2) Specific Lighting

Specific Lighting is warranted at:

a. Intersection where traffic signal is warranted and installed,

b. Crosswalk where pedestrian signal is warranted and installed,

c. Sections where cross section abruptly changes,

d. Sharp bend or steep slope,

e. Toll plaza and its approaches,

f. Sections where the ratio of night to day accident rate is more than 2.0,

g. Sections where a study indicates that lighting may be expected to significantly reduce the night accident rate.

5.4.3 Design of Highway Lighting

(1) Road and Area Classification

Lighting facilities should be designed taking account of the road class and brightness of surrounding area.

Roads discussed in this section are classified into three categories as following:

a. Major arterial road; The part of road system which serves as the most principal network mostly for through traffic flow.

b. Arterial road; The part of road system which serves as the principal network mostly for through traffic flow and supplements the network of major arterial roads.

c. Collector road; The part of road system which serves traffic between major arterial roads or arterial roads and local roads.

Since this classification is derived from the functional characteristics of road system, it does not directly correspond to DOH road categories. In principle, each road should be classified according to its function. However, following relations may exist between this classification and DOH roads if a rough grasp is allowed:

a. Primary national highways which have one- or two-digit route number may correspond to major arterial roads.

b. Secondary national highways which have three-digit route number may correspond to arterial roads.

c. Provincial highways which have four-digit route number may correspond to the collector roads.

Besides, condition of roadside area shall be classified according to the degree of glare as following:

a.	Roadside Condition A:	Vehicle traffic is continuously affectedby roadside illumination.
b.	Roadside Condition B:	Vehicle traffic is inter-mittently affected by roadside illumination.
c.	Roadside Condition C:	Vehicle traffic is scarcely affected by roadside illumination.

(2) Quality of Highway Lighting

There are four fundamentals which influence the quality of highway lighting, i.e.:

- Average road surface luminance,
- Luminance uniformity,
- Glare, and
- Visual guidance.

1) Average Road Surface Luminance

Contrast is one of the most important contributors to nighttime visual performance. The recognition of objects is mainly based upon discernment of brightness (luminance) differences between an object and its background. For night conditions, an obstacle may appear as a dark area against bright background (silhouette) or it may appears as a bright area against a dark background (reverse silhouette). Figure 5.7 shows the relationship between object visibility and brightness. Illumination is essential to enhance the discernment by silhouette.

Specification of roadway lighting of DOH has criteria as to average road surface illumination requirements that are shown in Table 5.9. Values of illumination are converted to those of luminance and indicated in parentheses.

According to the researches and experiments conducted in Japan, the minimum requirement of average road surface luminance (reference luminance) is 1 cd/m^2 when the luminance uniformity is kept to 0.4, while CIE (The International Commission of Illumination) has recommended 2 cd/m^2. DOH specification requires about 1.4 cd/m^2 for "main routes", which is a medial value of Japan and CIE. However, considering the high cost and expenses required for lighting facilities, 1 cd/m^2 is recommended as the reference luminance. Moreover, Japan has lots of practices with the reference luminance of 1 cd/m^2 which proved to be enough for roadway lighting.

Table 5.10 indicates the recommended reference luminances according to the road classification and roadside condition, where the reference luminance is reduced to 0.5 cd/m^2 which is presumed to be absolute minimum value to maintain the minimum visibility.

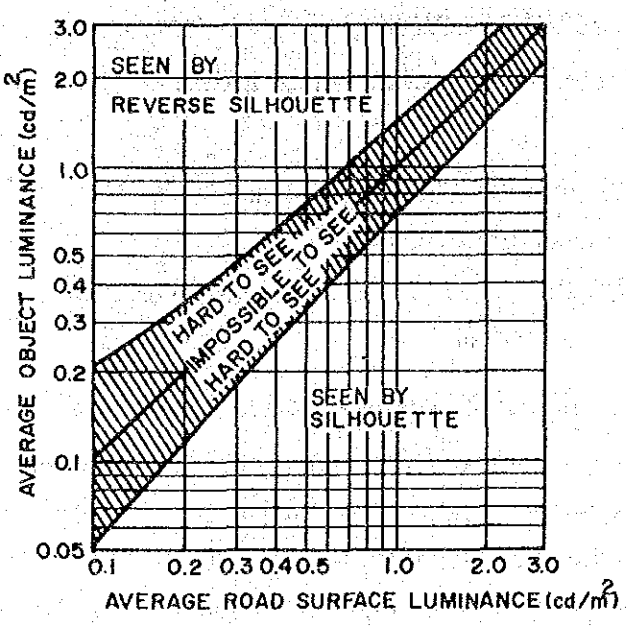


Figure 5.7 Relation between Visivility and Brightness

2) Luminance Uniformity

Uniformity of luminance is required to provide visibility and visual comfort to the driver. Recognition of obstacle is easy in the area with higher luminance, while it is difficult in the area with lower luminance. Difficulty is derived not only from lower luminance but from the deterioration of visual acuity caused by the light dispersion in the driver's eyes, when the uniformity of brightness is not maintained.

Table 5.9 Current Average Illumination (Luminance) Requirements

Unit : 1m/m2 (cd/m2)

	Central Urban Area	Suburban Areas	Rural Areas
High Grade Motorways	21.5 (1.43)	15.0 (1.00)	10.75 (0.72)
At Junctions	21.5 (1.43)	21.5 (1.43)	15.00 (1.00)
Main Routes	21.5 (1.43)	13.0 (0.87)	9.70 (0.65)
Secondary Routes	13.0 (0.87)	9.7 (0.65)	6.50 (0.43)
Local Roads	9.7 (0.65)	6.5 (0.43)	2.10 (0.14)

Note : Conversion from illumination to luminance is done assuming that pavement is asphaltic concrete.
(15 lm/m^2 = 1 cd/m^2)

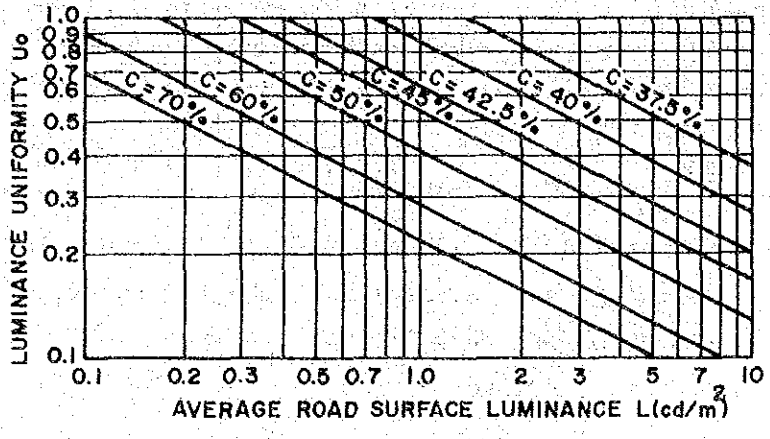
Table 5.10 Recommended Average Road Surface Luminance

Unit : cd/m2

Roadside Condition / Road Class	A	B	C
Major Arterial Roads	1.0 (0.7)	0.7 (0.5)	0.5 (-)
Arterial Roads Collector Roads	0.7 (0.7)	0.5 (-)	0.5 (-)

Note : Values in parentheses are applied to roads where median is furnished with glare screen.

Uniformity ratio is generally expressed as $L_{min}/\bar{L}$, where L_{min} is the minimum local luminance and $\bar{L}$ is the average luminance of the whole carriageway. Relationship between object visibility and luminance uniformity is shown in Figure 5.8, indicating a great influence of luminance uniformity. It is generally approved that uniformity ratio of 0.4 is proper for the minimum criterion. Appropriate uniformity of road surface luminance is attained by proper placement of luminaires.



NOTE: C IS "LUMINANCE RATIO", DEFINED AS FOLLOWING:

$$\frac{\text{AVERAGE ROAD SURFACE LUMINANCE}}{\text{OBJECT LUMINANCE}} \times 100 \quad (\%)$$

Figure 5.8 Thresholds of Object Recognition with Regard to Road Surface Luminance and Luminance Uniformity

3) Glare

There are two kinds of glare; discomfort glare and disability glare. Discomfort glare gives the psychological sense of discomfort, while disability glare induces the deterioration of physiological faculty of sight, inducing the light dispersion in eyes which becomes "noise" in sight information.

Since enough limitation of discomfort glare can minimize the influence of disability glare, consideration can be concentrated on discomfort glare.

Distribution of glare is affected by mounting height and number of luminaires as well as by the type of lighting apparatus, including cut-off, semi-cut-off and non-cut-off. Cut-off type is suitable for principal road for which limited glare is needed because glare is controlled restrictively

for this type. Semi-cut-off type is appropriate for the road where surroundings are comparatively bright, because the light distribution is not so limited as the cut-off type. Non-cut-off type is not generally suitable for roadway lighting. Table 5.11 is prepared for selection of the light distribution type.

Table 5.11 Selection of Light Distribution Type

Roadside Condition / Road Class	A	B	C
Major Arterial Road	semi-cut-off	cut-off	cut-off
Arterial Road Collector Road	semi-cut-off	semi-cut-off	cut-off

4) Visual Guidance

Drivers need to perceive or know beforehand the information about the change of road alignment and geometry. Longitudinal lane marking and post delineators can give, of course, such an information. Appropriately arranged lighting facilities also produce an outstanding visual guidance, while highway lightings arranged improperly may mislead the drivers.

Effective placement method of luminaires shall be discussed later.

(3). Highway Lighting Design

1) Light Source

Selection of light source should be done taking various aspects into account, i.e., efficacy, lamp life, stability to temperature, color rendering, etc. Following lamps are generally utilized for roadway lighting purpose:

- High-pressure sodium lamp,
- Low-pressure sodium lamp,
- Mercury vapor lamp,
- Metal halide lamp, and
- Fluorescent lamp.

Characteristics of these lamps are summarized in Table 5.12. Considering the features of each lamp, Table 5.13 is prepared for selection of light source.

Table 5.12 Characteristics of Typical Light Sources

Item \ Lamp	High-Pressure Sodium	Low-Pressure Sodium	Mercury Vapor	Metal Halide	Fluorescent
Wattage (W)	220	35	400	400	40
Luminous Flux (lm)*	40,000	4,600	21,000	30,000	3,000
Efficacy(lm/W)	87	78	47	65	55
Lamp Life (hr)	12,000	9,000	12,000	9,000	10,000
Light Color	Hazy Orange	Orange	White	White	White
Color Rendering	Average	Bad	Good	Good	Good
Dimming	Possible	Impossible	Possible	Impossible	Possible
Minimum Temperature for Usage (°c)	-20	-20	-5	-5	5
Maximum Starting Time	8	20	8	8	Negligible
Maximum Re-Starting Time	3	Negligible	10	15	Negligible

* Standard value used for design computation of roadway lighting.

Table 5.13 Suitability of Lamps

Road \ Lamp	High-Pressure Sodium	Low-Pressure Sodium	Mercury Vapor	Metal Halide	Fluorescent
Freeway, Expressway	◎	◎	○		
Inter-City Road	◎	○	○		
Urban Road	◎		◎	○	
Commercial Street			◎	○	◎
Road in Residential Area			◎		○

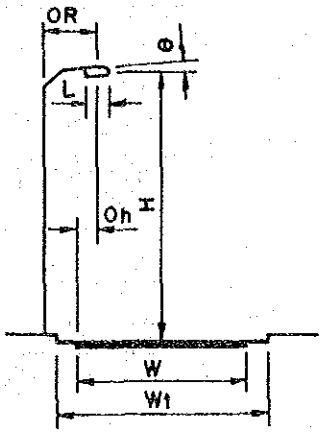
Legend ; ◎ : Recommended ○ : Suitable

In DOH road network, a lot of lighting facilities seem to be provided to important road sections such as intersections or other hazardous locations. The light source is, in most cases, low-pressure sodium lamp, which projects orange color light. This color is, however, very similar to that of flashing signal or "yellow" of traffic signal.

Adoption of low-pressure sodium lamp has an advantage of relatively high efficacy and accordingly low operation cost, but also has disadvantages such as lack of color rendition and relatively short lamp life. On the other hand, high-pressure sodium lamp is characterized by improved color rendering, long lamp life and high efficacy. Therefore, introduction of high-pressure sodium lamp seems to be reasonable.

2) Arrangement of Luminaires

The position of luminaire is determined by mounting height, overhang, inclination angle and placement type. Figure 5.9 shall be referred to for the explanation below.



W : WIDTH OF CARRIAGEWAY
Wt : WIDTH OF ROAD
H : MOUNTING HEIGHT
Oh : OVERHANG
OR : OUTREACH
θ : INCLINATION ANGLE
L : LENGTH OF LIGHT SOURCE

Figure 5.9 Basic Dimensions of Luminaire

Mounting Height of Luminaire

Generally speaking, the higher the luminaire is, the weaker the glare comes out. Also, higher luminaire gives the improved uniformity of luminance, while total construction cost increases. Mounting height of 10 to 15 m is generally regarded as economical.

Overhang

If the road surface is dry, greater overhang produces higher average road surface luminance. But when the road surface is wet, luminance of road edges or shoulders will be reduced drastically. Then, smaller overhang is appropriate considering the wet season.

Inclination Angle

Larger inclination angle can improve the brightness and luminance uniformity to some extent, but more than that, it increases the discomfort glare. Generally, less than 5 degree is adopted.

Placement of Luminaire

Basic types of placement comprise one-side placement, staggered placement, opposite placement and median placement, which are illustrated in Figure 5.10.

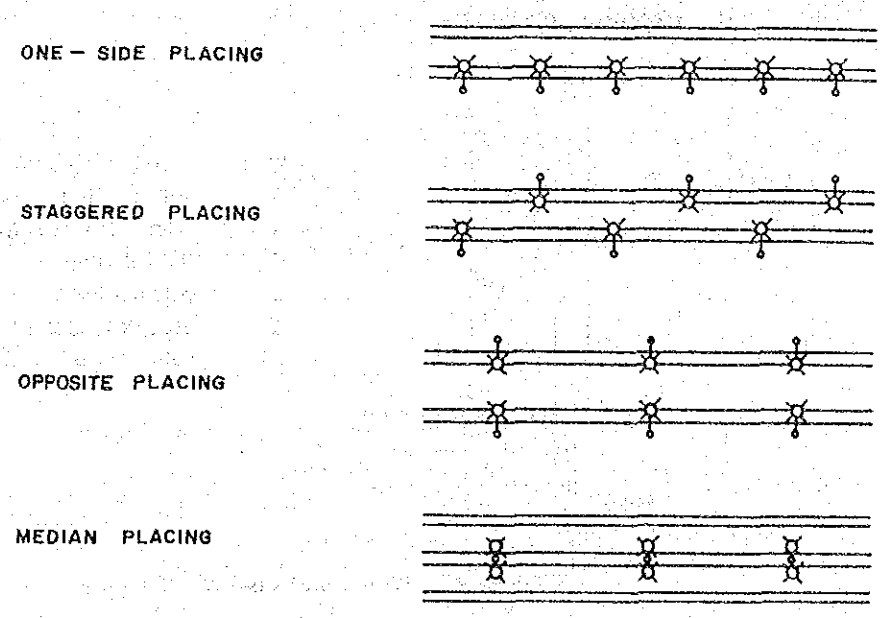
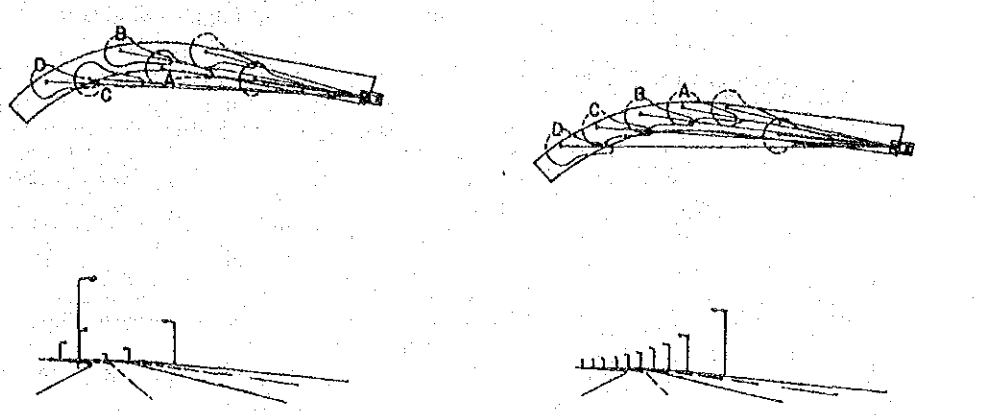


Figure 5.10 Typical Luminaire Placing Arrangements

When the continuous lighting system is planned at a curve section, visual guidance effect of luminaires should be considered. As to the type of placement, staggered placement is not adequate. On the contrary, application of one-side placement to the outer edge of the curve is generally recommended because of its good visual guidance effect. Comparison of perspectives from the driver's eyes is shown in Figure 5.11.



(a) STAGGERED PLACING AT A CURVE (b) ONE-SIDE PLACING AT A CURVE

Figure 5.11 Lighting Placing at a Curve

3) Design Criteria for Luminaire Positioning

Mounting height, overhang and inclination angle of luminaire shall be conformed to Table 5.14.

Practical mounting height and spacing of luminaire are determined by carriageway width, type of luminaire placement and type of light distribution. These can be obtained from Table 5.15.

As for the luminaire spacing along the outer edge of the curve, the criteria specified in Table 5.16 shall also be satisfied.

Table 5.14 Mounting Height, Overhang and Inclination Angle of Luminaire

Luminous Flux of a Light Source (lm)	Mounting Height (m) H	Overhang(m) Oh	Inclination Angle (deg.) θ
Less than 15,000	8 or more	$-1 \leqq Oh \leqq 1$ (lamp length < 0.6m) $-1.5 \leqq Oh \leqq 1.5$ (lamp length $\geqq 0.6$m)	
15,000 - 30,000	10 or more		5 or less
30,000 or more	12 or more		

Table 5.15 Mounting Height and Spacing of Luminaire

Light Distribution / Height and spacing / Type of Placement	Cut-Off		Semi-Cut-Off	
	Mounting Height(m) H	Spacing(m) S	Mounting Height(m) H	Spacing(m) S
One-Side Placement	≧ 1.0W	≦ 3.0H	≧ 1.1W	≦ 3.5H
Median Placement	≧ 1.5W	≦ 3.5H	≧ 1.7W	≦ 4.0H
Staggered Placement	≧ 0.7W	≦ 3.0H	≧ 0.8W	≦ 3.5H
Opposite Placement	≧ 0.5W	≦ 3.0H	≧ 0.6W	≦ 3.5H
	≧ 0.7W	≦ 3.5H	≧ 0.8W	≦ 4.0H

Note ; W is width of carriageway.

Table 5.16 Spacing of Luminaires along Outer Edge of Curve

Curve Radius (m) / Mounting Height	300 or more	250 to 300	200 to 250	Less than 200
No more than 12 m	35 or less	30 or less	25 or less	20 or less
More than 12 m	40 or less	35 or less	30 or less	25 or less

(4) Arrangement of Luminaires for Specific Lighting

1) Intersection

Luminaires at intersection should be placed so that the driver approaching to the intersection can easily recognize the vehicles and pedestrians in and near the intersection, and besides, the existence of the intersection can draw an attention of the driver from a distance.

Figure 5.12 shows examples of luminaire arrangement at a T-intersection and a cross intersection. The luminaire placements in this figure are determined so as to illuminate the turning vehicles clearly in particular. When the road has a median, two kinds of typical luminaire arrangement can be considered, as shown in Figure 5.13. If the continuous lighting is furnished along the median, opposite placing of luminaires at the intersection is recommended because such an arrangement gives the approaching drivers an information of the existence of an intersection. On the contrary, if the continuous lighting is furnished along both sides of carriageway, the median placing at an intersection is recommended.

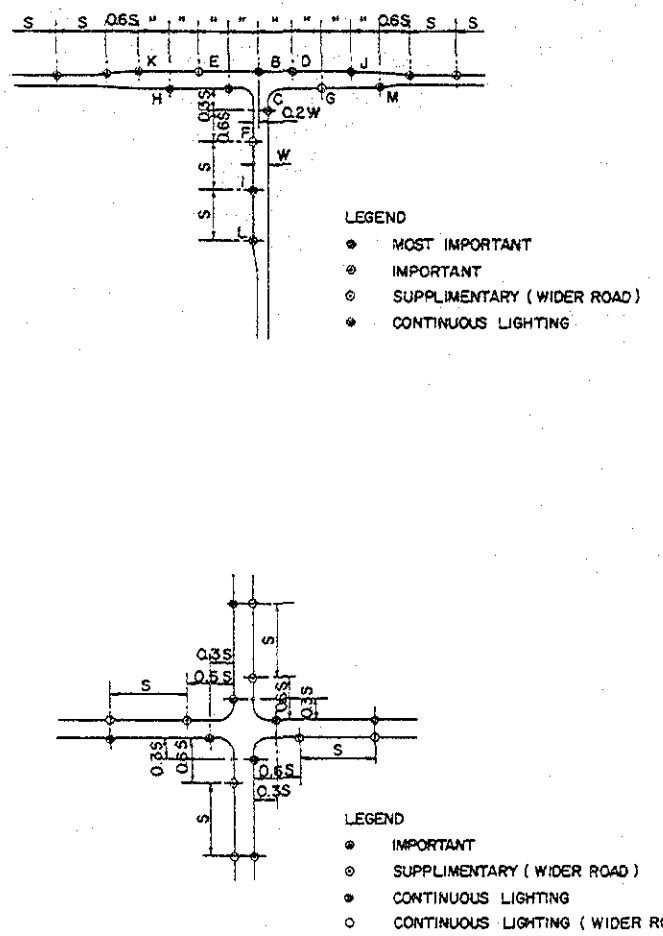


Figure 5.12 Typical Luminaire Arrangements (Intersections)

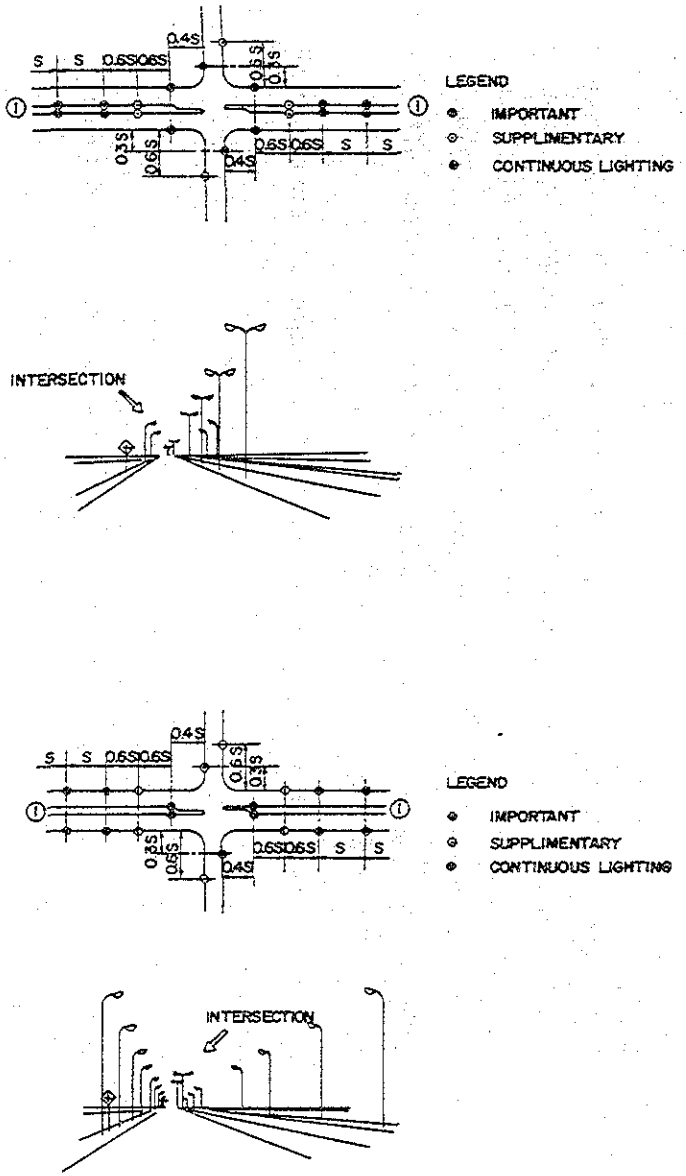


Figure 5.13 Typical Luminaire Arrangements (Indication of Intersection)

2) Crosswalk

Lighting at a crosswalk should be furnished so that the pedestrian is clearly lighted up. To assure the safety of pedestrian, he must be recognized by a driver from a distance of minimum 50 m, and this can be realized by illuminating the 35 m zone ahead from the crosswalk. In addition, to lighten the crosswalk itself is not considered effective because the silouette effect is impaired.

Figure 5.14 shows the typical arrangement of luminaires for the crosswalk lighting.

3) Pavement Width Transition

Specific lighting at pavement width reduction is exemplified in Figure 5.15. Identification of such a hazard is to be made easily.

4) Other Places

Specific lighting at a curve is explained in preceding paragraph. The lighting for other places such as bridge, slope, toll plaza, rest area, etc. can also be correspondingly applied in the same manners as discussed above.

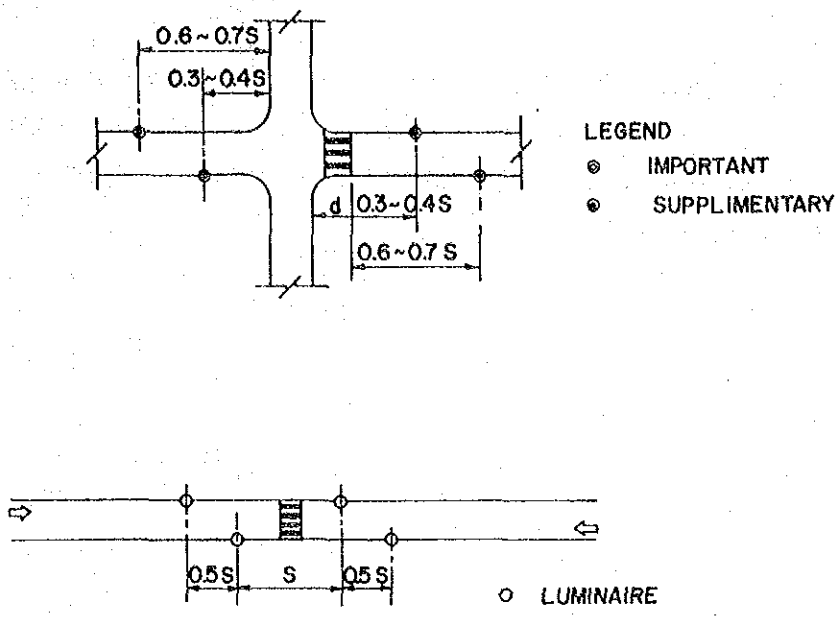


Figure 5.14 Typical Luminaire Arrangement (Crosswalk)

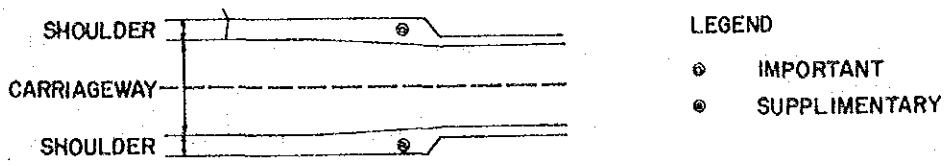


Figure 5.15 Typical Luminaire Arrangement (Width Transition)

5.5 Delineator

5.5.1 Delineation of Roadways

As discussed in Section 5.4 Lighting, drivers need various visual information at nighttime, among which roadway delineation is essential especially when carriageway is not illuminated. Effective delineation will improve the highway safety and ease the driving task.

Substantial delineation treatments include the following:

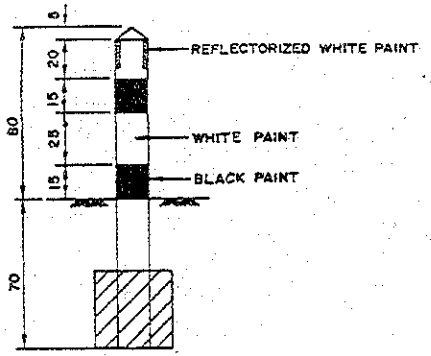
- post delineators,
- raised pavement markers,
- longitudinal pavement markings,
- curbs,
- guardrails,
- colored pavement, and
- rows of luminaires.

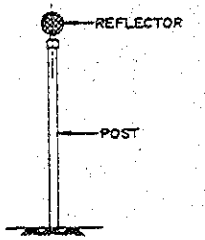
Among these treatments, post delineators and raised pavement markers are taken up in this section, while other important delineation treatments such as pavement markings, guardrails and rows of luminaires are dealt with in their respective sections of this chapter.

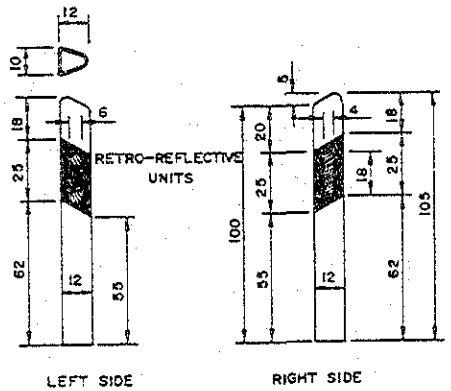
DOH has erected a large number of so-called "guide posts", at curves, approaches to bridges and other selected places. The guide post, made of concrete in a shape of quadrangular column, painted in white and black zebra with the height of about 0.8 m, is regarded as one form of post delineators when it is reflectorized at the top. Types of post delineators varies in shape and material; some of them are illustrated in Figure 5.16.

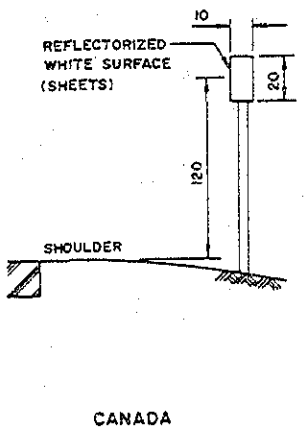
Raised pavement markers, meanwhile, include various types employed for guidance of vehicles, as exemplified in Figure 5.17. While shape, color and material vary extremely, raised pavement markers may be roughly classified as follows:

- Non-reflective markers,
- Reflective button,
- Reflective raised bar (so-called "Chatter bar"),
- Reflective curb marker,
- Intersection identification marker, and
- Other reflective markers.



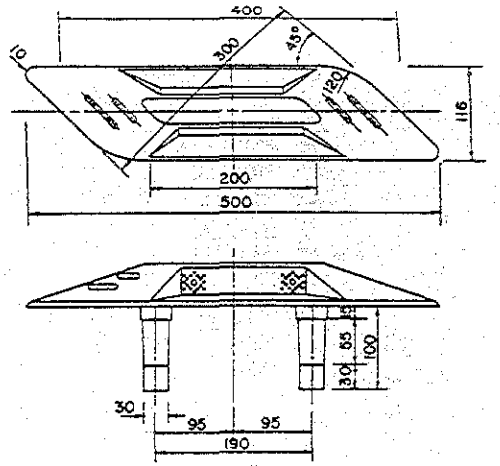


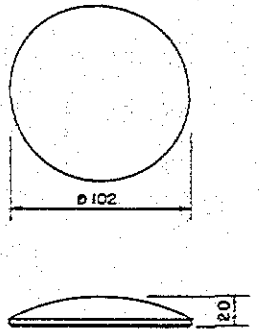


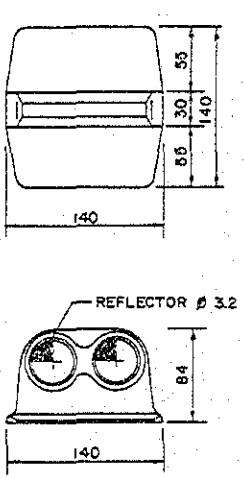


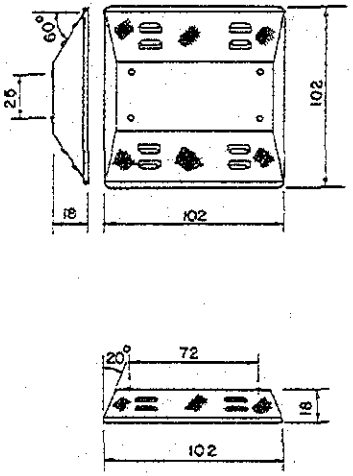
UNIT : cm

Figure 5.16 Various Post Delineators









UNIT : mm.

Figure 5.17 Various Raised Pavement Markers

From the standpoint of applications, several aims of raised pavement markers are listed as follows:

- to amplify longitudinal pavement marking,
- to restrain overtaking,
- to delineate curb line,
- to control vehicle speed,
- to channelize traffic,
- to identify intersection, and
- to identify hazardous location.

As there is no established practice for the selection of raised pavement markers, engineers are requested to select an adequate type so as to get sufficient efficacy of them, considering the characteristics of each type.

In this section, reflective raised bars will be mainly discussed since they are utilized and applied to various purposes and win general appreciation in Japan.

5.5.2 Warranting Conditions

(1) Post Delineators

Following remarks are found in "Manual on Traffic Control Devices" of DOH:

> In general, the delineators are used for the case of the horizontal or vertical change of route alignment, or where the pavement width is changed. However, the delineator could be considered to be used in tangent road section, if necessary.

In this manual of DOH, delineator is prescribed as a reflective material (it is usually a white reflective paint) placed on top of guide post. Since non-reflectorized guide posts can be nothing but hazards to traveling vehicles at night, except when they are installed in illuminated area, following discussion will not apply to non-reflectorized guide posts.

There are three types of road sections where delinators may be erected, as described in the manual, which are:

- horizontal or vertical curve sections,
- sections where pavement width changes, and
- tangent sections.

As there is a part of common roles between guardrails and post delineators, the warranting conditions for post delineators shall be discussed, referring to those of guardrails.

It should, however, be noted that post delineators are not so effective when guardrails are installed, because guardrails have high visual guidance effect especially when they are reflectorized partially.

According to warrants of guardfences, they are to be installed at curve sections having radius of 200m or less or downgrades of 4% or more.
As to post delineators, they can be applied more widely, because of their relatively low cost. Post delineator is generally recommended to curve sections having radius of 400m or less, while slopes are not necessarily provided with post delineators.

Post delineators are also to be installed along sections where number of lanes or width of carriageway changes abruptly because substantial guidance for drivers is needed peculiarly at such sections.

The installation of post delineators to tangent road sections is justified only when vehicle speed at night is relatively high and such installation is expected to effect a smooth and safe traffic stream or where there are many experiences of run-off type accidents at nighttime.

(2) Reflective Raised Bars (Chatter Bars)

Chatter bars have been placed in various cases in Japan. They have two aspects in effectiveness, one is delineation effect by reflective unit, and the other is rumble effect which alerts inattentive drivers. Chatter bars are very effective when applied to road sections where traffic is to be channelized and visually guided at nighttime.

As a small radius curve, vehicle running on inner lane often drives on a part of opposite direction lane to avoid intense centrifugal effect, which possibly leads to a disastrous head-on collision. Installation of chatter bars along centerline at such small radius curve is very effective. This has been proved effective through the experimental work on route 306 of DOH road. The inclination to drive on opposite lane is related to "easiness of driving". Assuming that approaching speed is 60 km/hr, 150m of curve radius is considered as a minimum limit for easy driving according to lateral force calculation.

Even the tangent road sometimes should be divided physically along the centerline. One case is undivided multilane road, another is section where overtaking is prohibited. Roads having 4 lanes or more are, in principle, to be divided by median to prevent intensive head-on collision accidents. Chatter bar installation is effective when construction of mounded and curbed median is restricted or when access and egress traffics frequently cross the centerline.

Another effective use of chatter bars is to stress the boundary of chevron markings. To mark clearly channelization at night and to alert careless drivers by rumble effect, the placement of chatter bars along the boundary of chevron marking contributes to safety, especially when such marking is drawn closely to rigid hazards, e.g., raised traffic island, pier in the carriageway, etc.

(3) Summary of Warrants

1) Post Delineator

Post Delineators may be installed along the following sections except where guardrails are installed:

a. Curve sections of which radius is 400m or less, and approaches to the curve,

b. Sections where number of lanes or width of carriageway changes abruptly,

c. Sections where there are many accident records of run-off type at nighttime or where found as necessary by engineering study to ensure safe traffic flow.

2) Raised Pavement Marker (Chatter Bar)

Series of Raised Pavement Markers may be installed along:

a. Curve sections of which curve radius is 150m or less,

b. Sections where centerline crossing by vehicles is to be prohibited,

c. Boundary of chevron marking which is drawn on the pavement near to rigid hazards, e.g., raised traffic island, pier in the carriageway, etc.

5.5.3 Application

(1) Post Delineator

1) Horizontal Curve

In the Manual of DOH, spacing of delineators at a horizontal curve is determined under the condition that the motorist can observe at least 5 delineators. These criteria are graphed in Figure 5.18 together with those of Japan, which are based on the equation $S = 1.1\sqrt{R-15}$. Both seem similar to each other. This figure indicates that spacing criteria of DOH are considered as adequate.

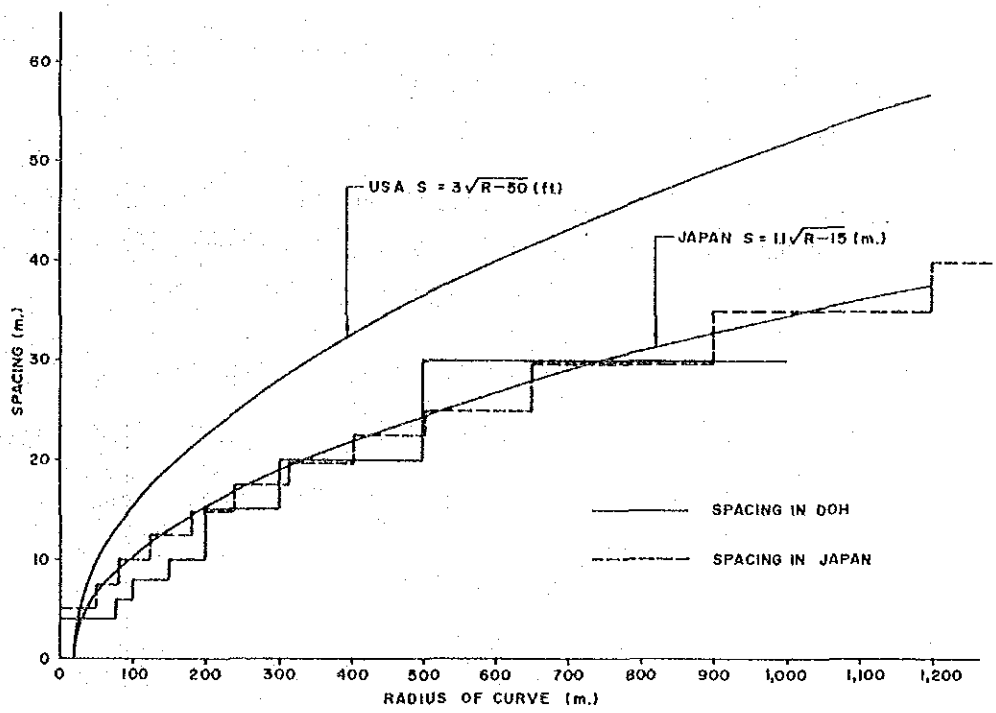


Figure 5.18 Spacing of Post Delineators

From the visual standpoint, use of post delineators on the outside of curve only is effective enough. However, post delineators used on both side make the carriageway clearer. In this case, two-color system, i.e. white for left side and orange for right side from the driver, may be more effective, but as long as current shape of post delineator in DOH is employed, introduction of two-color system has a difficulty. Therefore, single color system (i.e. white) is recommended except for warning purpose.

2) Pavement Width Transition

Changing the color of reflective unit (from white to orange) and shortening of the spacing of post delineators in the area where the pavement width reduces will provide advance warning of change.

Use of post delineators on both sides of the road may further emphasize hazardousness, and promote slower and more attentive approaches.

3) Tangent Section

Post delineators should be installed along the left side of roads with a spacing of 40m.

(2) Raised Pavement Marker (Chatter Bar)

1) Horizontal Curve

Positive application of chatter bars along the centerlines of sharp curves will have a remarkable effect on safety improvement. Spacing of chatter bar should comply with figures in Table 5.17.

Table 5.17 Spacing of Chatter Bars

Curve Radius (m)	Spacing (m)
Less than 50	2
50 to 300	3
300 or more	4

2) Use as Substitute for Median

One effective usage of chatter bars is to install along center line to make it work as a simple median. The height of chatter bar is about 5cm from the pavement surface, and it may give the vehicle running in considerable speed an intense rumble effect which discourage the driver to cross the center line, while it allows the vehicle to cross the line of chatter bars easily when moving slowly. Simple median comprised of chatter bars, therefore, is useful and effective when it is applied to sections where separation of counter-directional traffics is required and besides, access and egress of vehicles from and to the neighboring areas should be viable. Figure 5.19 is a typical application for above usage.

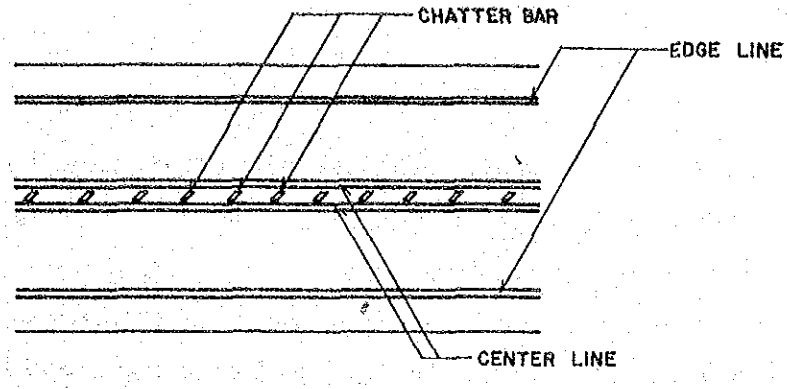


Figure 5.19 An Example of Simple Median Making Use of Chatter Bars

3) Enhancement of Zebra Marking

Zebra marking to channelize the traffic flow is one of the principal measures to enhance the safety and capacity of intersections. But as is often the case with the channelization by painting, drivers tend to disobey his way indicated by means of zebra marking, and this leads to restricted efficiency of channelization. In such case, installation of chatter bars along the boundary of zebra marking is recommended. Chatter bars installed as indicated in Figure 5.20 will guide and delineate the way of drivers effectively through its rumble effect and optical guidance by reflective unit.

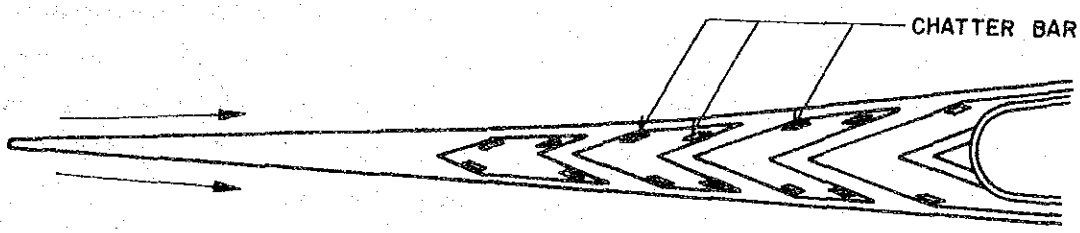


Figure 5.20 Enhancement of Channelization by Chatter Bars

5.6 Sidewalk and Bicycle Path

5.6.1 General

According to the accident statistics of DOH roads in the years of 1981 and 1982, the accidents involving pedestrians or bicycles account for 18% and 34% on the rural roads and urban roads, respectively.

In order to reduce the accidents at locations where their traffic volumes are high, it is a general practice to separate the traffic of pedestrians and bicycles from the vehicular traffic, by providing exclusive road spaces for pedestrians and bicycles.

The construction of the sidewalk for pedestrians and bicycle path for bicyclists does not only contribute to the safety of pedestrians and bicyclists, but also enhance the safety of vehicular traffic because it reduces reckless emergings of pedestrians and bicyclists. It can also contribute to improving the traffic capacity and traveling speed.

In practice, the sidewalk and bicycle path can be constructed either independently or in the form of their combination. In this study, warranting conditions on the following paths (hereinafter referred to as slow-traffic path) are prepared;

- sidewalk,
- bicycle-pedestrian path, and
- sidewalk plus bicycle path.

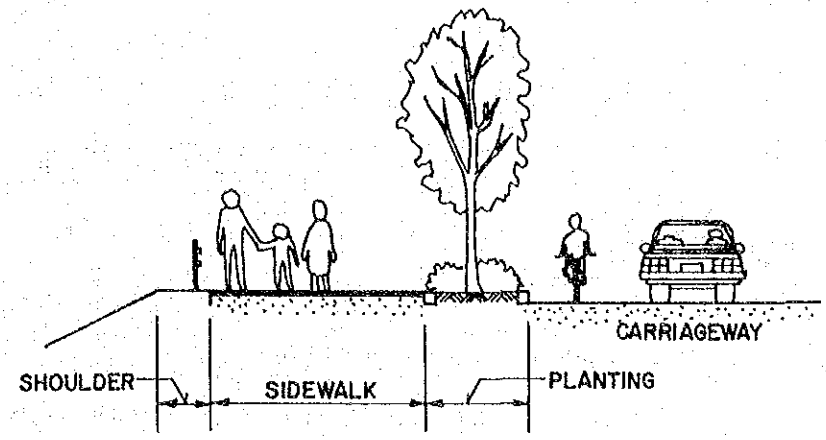
The sidewalk is the path for only pedestrians, while bicycle-pedestrian path is regarded as a bicycle path permissive of pedestrian traffic on it. In the case of sidewalk plus bicycle path, where the bicycle path is constructed alongside the sidewalk, they should be exclusive to each other. Figure 5.21 illustrates conceptional cross sections of the slow-traffic paths.

5.6.2 Warranting Conditions

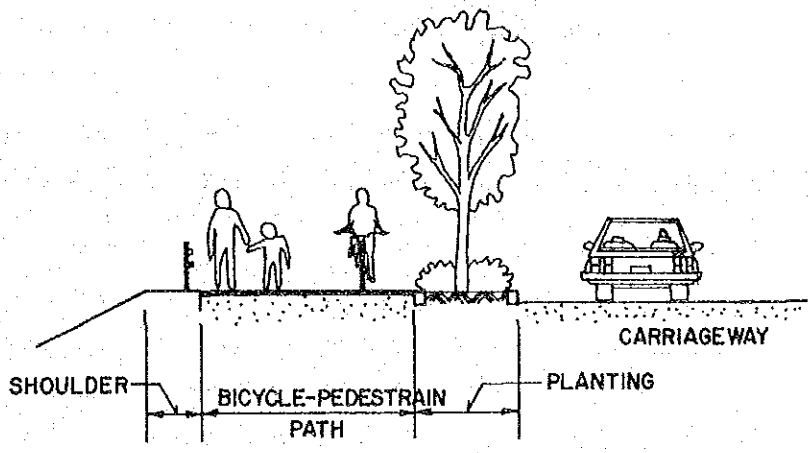
(1) Basic Frame of Warrants

Warranting conditions for slow traffic paths are discussed as to the following.

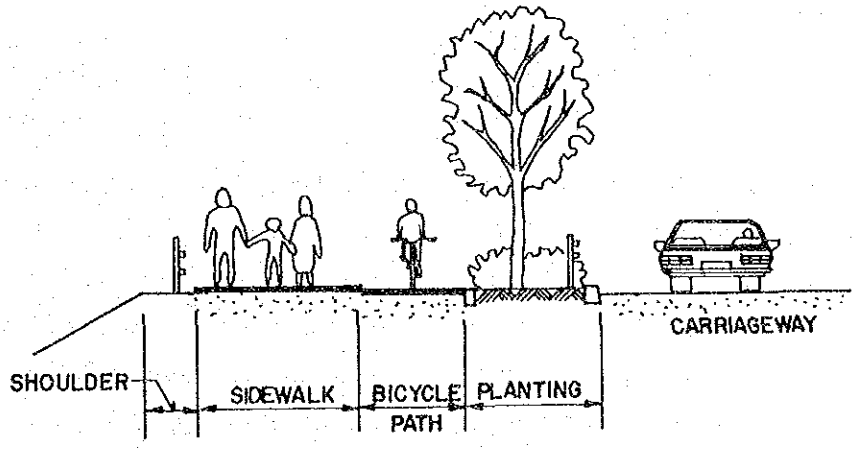
a. Requirement for segregation of pedestrians,
b. Requirement for segregation of bicycles, and
c. Requirement for separation of pedestrians and bicycles.



SIDEWALK



BICYCLE - PEDESTRIAN PATH



SIDEWALK PLUS BICYCLE PATH

Figure 5.21 Typical Types of Slow-Traffic Path

Construction of each slow traffic path is justified when:

a. Requirement a) is met, Sidewalk;
b. Requirement b) is met, Bicycle-pedestrian path;
c. Requirement b) and c) are met, Sidewalk plus bicycle path.

(2) Segregation of Pedestrians

Whether pedestrians should be segregated or not shall be determined by considering pedestrian volume and vehicle volume.

It may be considered rather dangerous if a pedestrian walking on a road is passed by motor vehicles every 30 seconds. When the speeds of vehicle and pedestrian are 60 km/hr and 4 km/hr, respectively, above situation is created by vehicular volume of 260 veh/hr, which corresponds to approximately 3,000 veh/day.

On the part of a driver, every 15 second encounter with pedestrians may be hazardous. 35 persons per hour or 250 persons per day creates such condition.

When above two requirements on traffic volume are satisfied, sidewalk construction may be warranted. This warrant, however, should be applied only to rural roads because sidewalk in urban area should be considered not only from the traffic safety point of view but social requirements as well as city planning. Then, sidewalk construction in builtup areas could be justified at the lower level of traffic volume than rural area.

(3) Segregation of bicycles

Bicycle volume, vehicle volume and vehicle speed shall be considered to determine the warrants to segregate bicycle traffic from motor vehicles.

Bicycle traffic often decreases the traffic capacity of road because of its slow speed and unstable riding. The degree of obstruction to the vehicular traffic caused by bicycle increases sharply as the traffic volume increases. It is known that a bicycle is equivalent to one passenger car from the standpoint of traffic capacity when the passenger car volume per hour is 200 to 250 on two-lane road. This volume corresponds to approximately 2,000 vehicles per day. This traffic volume could be a threshold as to vehicle volume. As being the case with the pedestrian, the situation in which vehicle passes bicycles every 30 seconds is assumed as dangerous. Such a situation is created by 120 bicycles per hour or 1,000 bicycles per day.

Even when the bicycle volume per day does not reach 1,000, if the vehicle speed is considerably high and it endangers cyclists, bicycle traffic shall be segregated at the lower volume such as about 500 bicycles per day.

(4) Separation of Pedestrians and Bicycles

The requirement to separate pedestrians and bicycles depends largely on the degree of friction between the two movements. When the total volume of pedestrians and bicycles exceeds 3,000 per day, it is expected that the conflicts between them leads to a confused and dangerous traffic flow. Then, this figure may be the threshold whether pedestrians and bicycles should be separated or not.

(5) Paving the Shoulders

Preceding sections have dealt with warranting conditions of the slow traffic paths. However, their constructions are costly, and it is necessary to consider low-cost alternatives. The simplest method is to draw clear edge lines on roadway and designate shoulders as crosswalks or bicycle paths. Installation of raised pavement markers along the edge line might make them clearer and safer. But when the shoulders are not paved, as is often the case with DOH roads, they ought to be paved. Paving the shoulders may make a safer condition not only for slow traffic but also for vehicle traffic.

(6) Summary of Warrants

1) Sidewalk

a. Vehicle traffic* per day is 3,000 or more and pedestrian traffic is 250 or more. (For the roads in urban areas, it is desirable, regardless of the above traffic volume, to construct sidewalk on any road, when found necessary to do so and no land acquisition problems exist.)

2) Bicycle-pedestrian path**

a. Vehicle traffic* is 2,000 or more and bicycle traffic per day is 1,000 or more, or

b. Vehicle traffic* is 2,000 or more and bicycle traffic per day is 500 or more, when vehicle speed is considerably high.

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* Vehicle traffic travelling on outer lanes of both directions.

** Bicycle path permissive of pedestrian traffic.

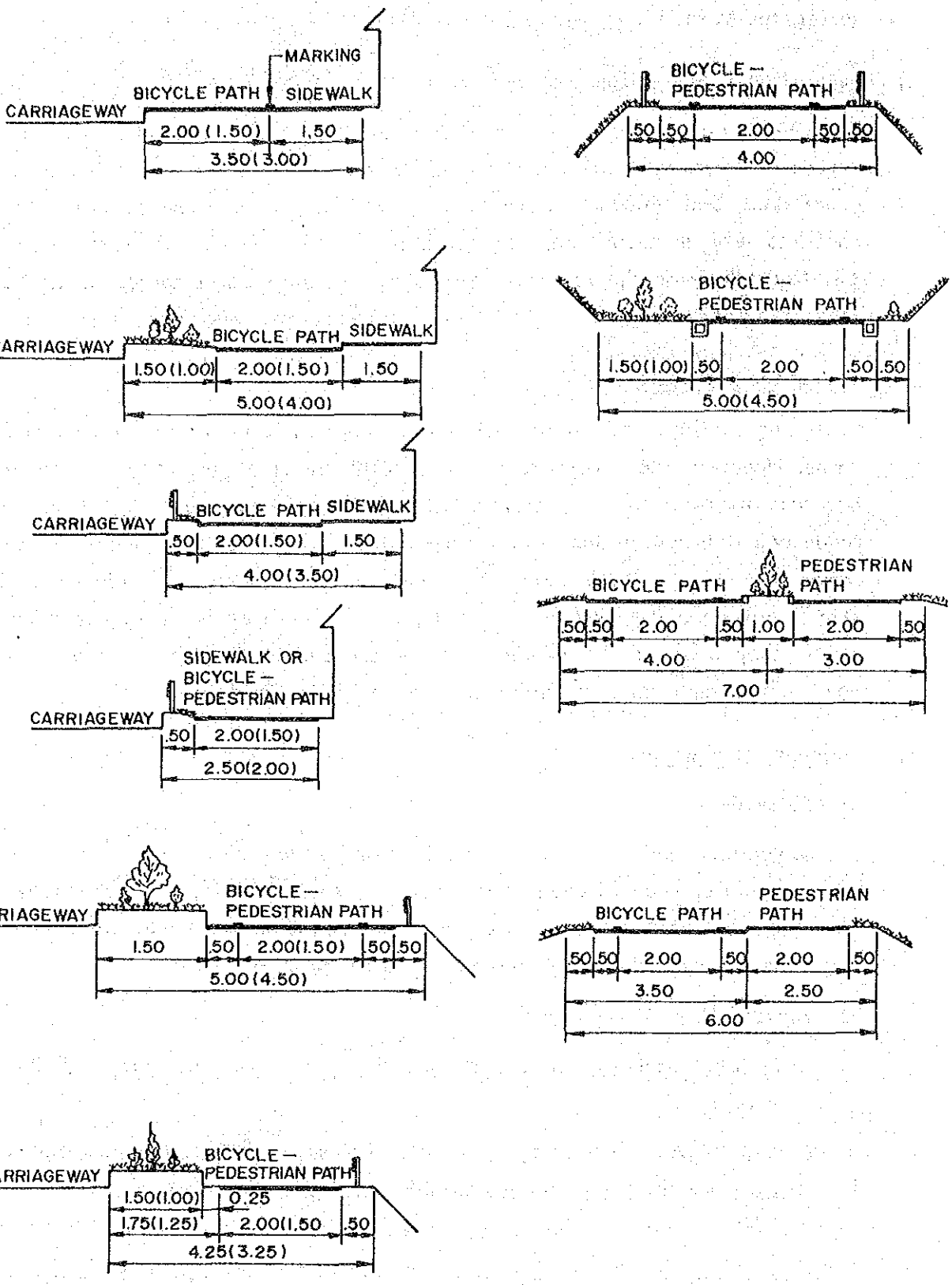


Figure 5.22 Typical Cross-sections of Slow Traffic Paths

3) Pedestrians and bicycles

The total volume of pedestrians and bicycles exceeds 3,000 per day.

Note: Where two or three of the above warrants are satisfied simultaneously, the priority is in order of 3), 2) and 1).

5.6.3 Design Information

(1) Cross Section

Several typical cross sections of slow traffic paths are shown in Figure 5.22 for reference. Following discussions deal with three components of cross section, i.e., pathway width, shoulder and vertical clearance.

1) Minimum Width of Pathway

Assuming the occupied width of a pedestrian as 0.6m, the unit width of a row of pedestrians (that may be called as a "lane") shall be 0.75m including marginal spaces (refer to Figure 5.23 as to the occupied width). Although the occupied width of a bicycle is the same as that of pedestrian, a unit "lane" width of bicycle requires 1.0m because of the unstable lateral positioning.

The width of pathway is to be determined by traffic volumes as well as their moving patterns as illustrated in Figure 5.24. The minimum widths are summarized in Table 5.18.

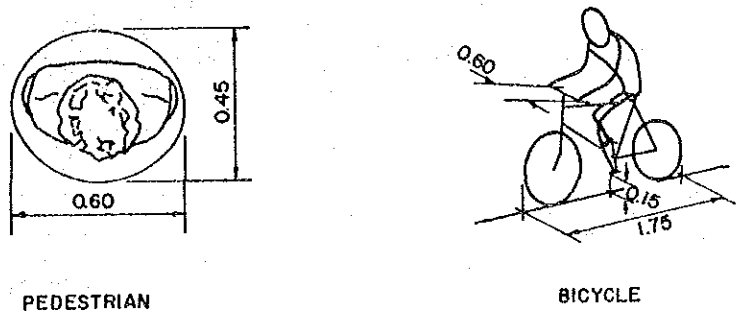


Figure 5.23 Dimensions of Pedestrian and Bicycle

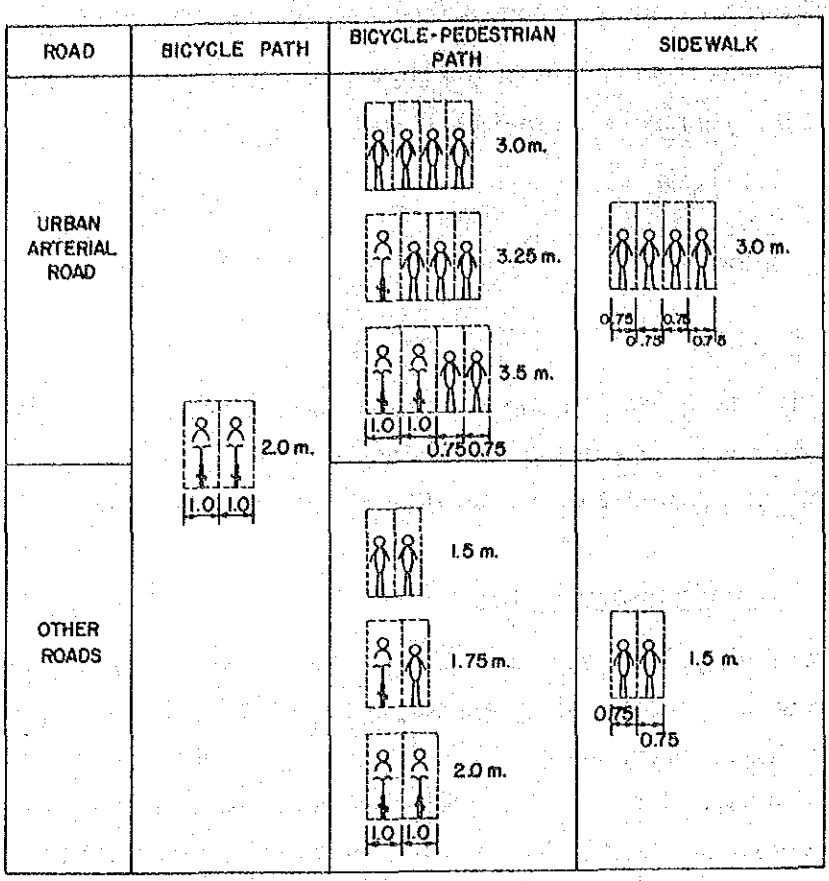


Figure 5.24 Minimum Width of Slow-Traffic Paths

Table 5.18 Minimum Width of Pathway

Slow Traffic Path / Road	Bicycle Path	Bicycle-Pedestrian Path	Sidewalk
Urban Road	2.0 (1.5)	3.5 (2.0)	3.0 (1.5)
Other Roads	2.0 (1.5)	2.0 (1.5)	1.5 (1.0)

Note : Reduced values in the parentheses shall be applied when (1) volume of slow traffics (pedestrian or bicycle) are relatively small, or (2) planned on bridge longer than 50m.

The width of a bicycle path should be determined taking the traffic capacity into consideration. "Traffic capacity of bicycle path" means a maximum bicycle volume of a lane which allows the bicyclists to ride easily and comfortably. Table 5.19 shows the basic traffic capacity of bicycle path, which was determined through the experiment and the observations. With this table and the bicycle volume, the width of a bicycle path can be determined; i.e., the bicycle volume less than 2,000 per hour requires 2 lane or width or 2m, 2,000 to 3,000 requires 3m, and more than 3,000 requires 4m-wide pathway.

Table 5.19 Traffic Capacity of Exclusive Bicycle Path

Lane Number	Bicycles Per Hour
2	2,000
3	3,000

The traffic capacity of bicycle-pedestrian path is, however, affected by pedestrian traffic. The adjustment factor of the capacity for pedestrian traffic mixture is assumed as 0.8 when the pedestrian volume is about 200 to 400 per hour. The traffic capacity of bicycle-pedestrian path is indicated in Table 5.20, from which the width of bicycle-pedestrian path is determined in the same way as bicycle path.

Table 5.20 Traffic Capacity of Bicycle-Pedestrian Path

Lane Number	Bicycles Per Hour
2	1,600
3	2,400

As to the sidewalk, it is quite difficult to decide the capacity, because the pedestrian volume varies drastically, even in a five-minute measuring duration, and additionally, pedestrian traffic changes its feature according to the trip purpose, sex and age. Therefore, final decision shall

be made by concerned engineers, taking account of the characteristics of the pedestrian traffic as well as its volume.

2) Shoulder

Shoulder set out here has following multipurpose functions as following:

- to protect the main structure of pathway from erosion;
- to produce a space for the appurtenances (e.g. guardfence or traffic sign);
- to produce a space for planting;
- to make a lateral clearance for the use of stopping or passing each other; and
- to improve the amenity for users.

Except for the space for planting, 0.5m wide shoulder is enough for respective purposes in most cases. Planting space may require 1.0 to 1.5m. It can be said, however, that the width may be reduced to 0.25m on bridges or on the sections under specific restrictions.

3) Vertical Clearance

The height of a cyclist or a pedestrian can be assumed less than 2.0m. Accordingly, vertical clearance of 2.5m for the bicycle(-pedestrian) path and sidewalk is recommended.

(2) Separation Methods

There are varieties of measures to separate slow traffic from high-speed traffic. They vary from the simple one of edge line marking to the complete one of raised path with a guardfence and planting. Typical measures of separation are exemplified in Figure 5.25.

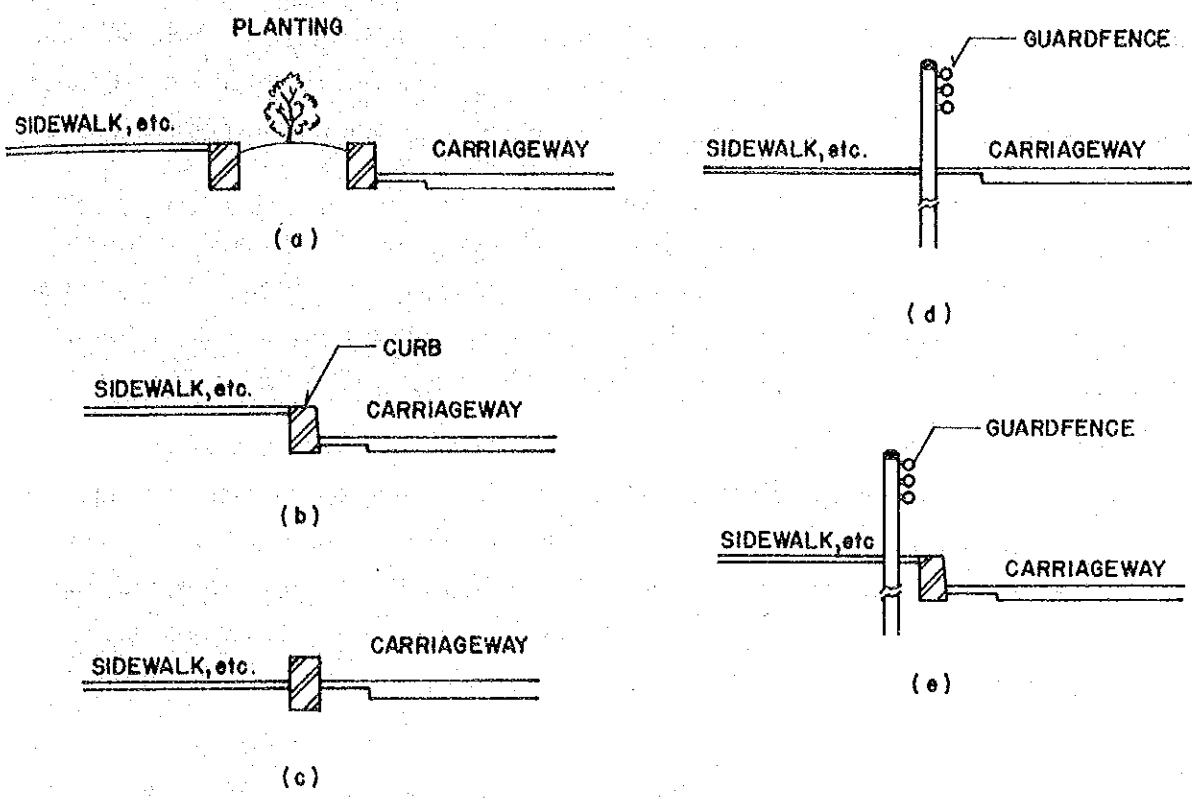


Figure 5.25 Various Methods of Slow Traffic Segregation

5.7 Crossing Facility for Pedestrian

5.7.1 General

The main objective of crossing facilities is to ensure pedestrians' safety when they cross roads, through elimination or reduction of conflicts between vehicles and crossing pedestrians. The crossing facilities also contribute to minimized vehicular traffic delay which may be caused by disorderly movements of pedestrians on roadways without them.

Crosswalk, refuge island, pedestrian signal, and pedestrian overpass and underpass are well known and practical facilities for pedestrian crossing. Since the degree of effectiveness and obstruction to vehicles as well as construction costs varies with types of the facilities, careful consideration should be paid to select best suited facility at a given location.

Although detailed discussions on the features of the crossing facilities are made in the following section, some of them, by the nature of complexity, are rather subjective but neither objective nor conclusive. It should, therefore, be noted that a final decision on selection of type and location of crossing facilities should be made by the concerned engineer who is acquainted with road and traffic conditions at specific locations.

Excluded in the following discussions is the pedestrian signal which has been explained in section 5.2, "Traffic Signal".

5.7.2 Warranting Conditions

(1) Crosswalks

Crosswalk is a part of roadway designated as a pedestrian walking area which provides pedestrian road space to cross the carriageway safely. It is particularly desirable to indicate crosswalks by markings so that they are visible by day and by night. The clearly marked crosswalk will attract pedestrians and warn vehicle drivers when they approach to the crosswalk.

It is noteworthy that crosswalks accompanied with adequate safety devices like flashing beacon, lighting and warning sign are more effective. Installation of pedestrian guardfences plays an important role to make crosswalk effective, when they are properly erected so as to guide pedestrians into crosswalk preventing reckless and random crossings.

There are no definitely accepted warrants for painted crosswalks, but they should be based upon;

- pedestrian volume crossing roads,
- vehicular volume and speed,
- accident frequency, and
- use as school crossings.

For pedestrian volume, crosswalks are generally warranted at locations where there are at least 100 crossing pedestrians per hour. To ensure sufficient traffic gap for 100 pedestrians per hour, the maximum vehicular traffic volume can be estimated at about 450 vehicles per hour. The minimum intervals of crosswalks should be decided based upon the requirement of smooth vehicular traffic flow. Although there exist conflicts between pedestrian safety and smooth traffic flow, the minimum interval of around 200m seems to be a reasonable compromise for the conflicts.

(2) Pedestrian Refuge Island

The refuge island is a safety zone built in the middle of the carriageway for the exclusive use of pedestrians, where there are heavy vehicular traffic and high volume of pedestrians who would face difficulty and danger in crossing a wide carriageway at one movement. With the provision of the refuge island, in the middle part of the carriageway, pedestrians can safely wait for a traffic gap sufficiently long enough to complete the crossing.

The refuge island may also be desirable for wide streets where intersection is controled by signal, to reduce the necessary clearance period in accordance with traffic movement without creating a dominant gap for pedestrian to cross the street.

To increase effectiveness of the refuge island, it is preferable to provide a combination of some adequate devices like pedestrian crosswalk and lighting.

(3) Pedestrian Overpass

The pedestrian overpass is the most effective means to attain the safety of road crossing pedestrians, since it completely separates pedestrians from vehicles on roadways.

However, its high construction cost often restrains the installation of overpasses, and pedestrians sometimes prefer to crosswalk at grade because of longer walking distance and extra loss of energy for up and down of stairways.

The pedestrian overpass, therefore, may be justified at extremely hazardous locations where there are high volumes of vehicular and pedestrian traffics, and there are high frequency of accidents involving pedestrians which can not be solved by some simpler or more economical ways. Similar argument is applied to pedestrian underpasses.

A comprehensive evaluation of crosswalk and pedestrian overpass, should be made prior to the installation of an pedestrian overpass. The most fundamental factor in the study is the "time gap" of the traffic, during which pedestrians can cross roadway at grade.

There exists the following equation between time gap and number of crossing pedestrians.

$$G = \frac{W}{V} + t + f(n) \qquad (1)$$

where,

G: necessary time gap for pedestrians to cross roadway (sec),
W: width of carriageway (m),
V: walking speed of pedestrians (m/sec),
t: pedestrian's reaction time (sec) (usually negligible), and
f(n): some sort of function
n = pedestrian volume per hour.

From the results of various studies and experiences, the above equation can be simplified as follows;

$$G = \frac{W}{1.3} + 2(N-1) \qquad (2)$$

where,

N is number of pedestrian rows. (See Table 5.21 below)

Table 5.21 Number of Rows for Pedestrian

Number of Pedestrian (persons/hour)	Number of Rows
100 - 300	1
301 - 600	2
601 - 900	4
901 -	6

Note: Prepared based on the assumption that pedestrian cross roadway five abreast in a row.

Meanwhile, the probability that the number of vehicles which arrive at a certain road section: (TG/3600; T = traffic volume/h), can be assumed to follow the Poison's distribution.

$$P(k) = \frac{e^{-TG/3600}(TG/3600)^k}{k!} \qquad (k=0,1,2...) \qquad (3)$$

When traffic volume per hour is T, provided that one vehicle in each direction of road is requested to stop for crossing pedestrian during the time period of G, the traffic volume of T under which G occurs once every 60 seconds, can be obtained from the following equation.

$$\sum_{k=0}^{2} P(k) = \sum_{k=0}^{2} \frac{(\frac{TG}{3600})^k \cdot e^{-(\frac{TG}{3600})}}{k!} \leqq \frac{G}{60} \qquad (4)$$

From the equations (2) and (4), and Table 5.21 a warrant for pedestrian overpass can be proposed as shown in Figure 5.26.

(4) Summary of Warrants

1) Crosswalk

Crosswalk may be installed where:

a. a number of school children cross roadway,

b. designated as walking parts within an intersection, and

c. vehicular traffic makes it difficult for a number of pedestrians to cross roadway.

2) Pedestrian Refuge Island

Pedestrian refuge island may be installed at the sections where pedestrians can not cross carriageway in one movement of crossing and forced to wait for a traffic gap in the middle part of roadway of which carriageway has 4 lanes or more.

The pedestrian refuge islands should, in principle, be installed in combination with crosswalk.

3) Pedestrian Overpass

Pedestrian overpass, at roadway or at non-signalized intersection, is warranted under the following conditions.

a. The number of pedestrians per hour exceeds 100 persons at a peak hour, and the condition of vehicular volume and width of carriageway meet the range indicated by the oblique line in Figure 5.26. (For the crossing of school children, Figure 5.27 should be used.)

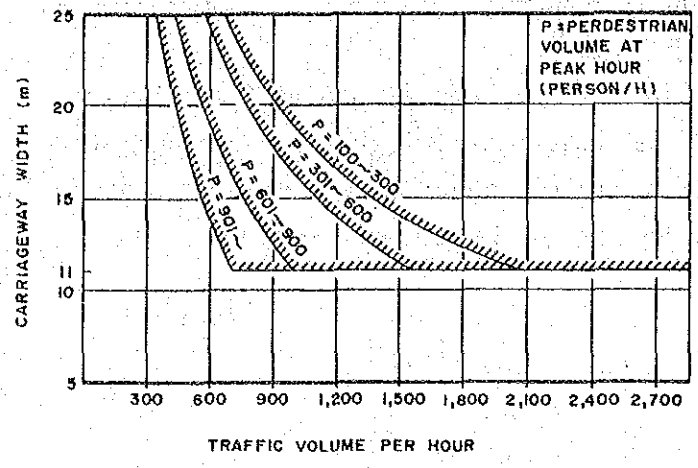


Figure 5.26 Warrant of Pedestrian Overpass

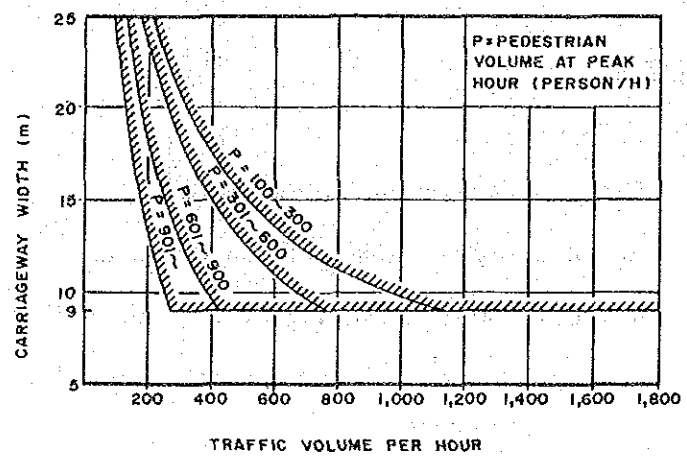


Figure 5.27 Warrant of Pedestrian Overpass for School Children

b. The following conditions are met:

- the width of carriageway exceeds 25 meters, and there are no proper space to construct median or refuge island where pedestrian can wait for traffic gap;
- pedestrian's volume is so high that vehicular traffic is affected to a large extent;
- no pedestrians are allowed to cross to ensure high running speed of vehicles on roads such as freeway; or

- when pedestrian's volume is high at such as locations, within 200 meters from railway crossing, immediate vicinity of grade-separated road, or sub-standard sight distance, where pedestrian safety cannot be kept by at-grade crossing.

5.7.3 Planning Methods

(1) Pedestrian Crosswalk

1) Type of markings for crosswalk

There are three kinds of road marking for crosswalk, namely, zebra marking with white road paint, two parallel solid lines with white colour road paint and two parallel dotted lines with road studs. The zebra markings are superior to other types of marking in visibility of crosswalk's existence.

2) Planning conditions

It is desirable to plan crosswalks in the following manners.

- The standard width of crosswalk should be 4.0m. The width may be increased or decreased according to pedestrian volume, but the minimum width be 3.0m;
  pedestrians to cross the road in one movement;
- Stop line shall be painted in association with the crosswalk marking; and

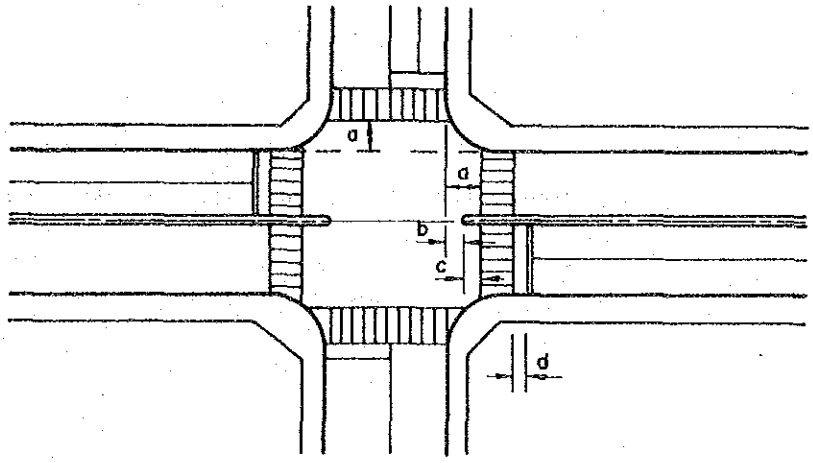


Figure 5.28 Crosswalk Planning at Intersection

- The minimum interval of crosswalks shall be 200m in urban area and 300m in the other area with exception of the areas in the vicinity of school, hospital, and where pedestrian volume is high enough to justify installation of other crosswalks in spite of the above minimum intervals.

(2) Pedestrian Refuge Island

It is desirable to plan refuge islands in the following manners.

- The minimum width of island shall be 2.0m,
- The refuge island should be protected from direct collisions by vehicles by means of guardfence, curbstone and the like.
- The island should be provided with adequate devices by which the vehicle drivers approaching to or passing by the refuge island, could be warned of the existence of the refuge island. The following are main warning devices;

  a. Pavement marking,
  b. Traffic sign,
  c. Delineator,
  d. Flashing beacon,
  e. Raised bar or road stud, and
  f. Street lighting.

(3) Pedestrian Overpass

Because a pedestrian overpass is a permanent structure and its construction cost is high, it is, unlike other crossing facilities, very hard to remodel a pedestrian overpass in accordance with the change of pedestrian traffic in the future.

Therefore, a thorough study on overpass especially as to structural dimensions is strongly required in advance of construction. The following are standards for overpass designs.

a. Width of footpath

The necessary width is theoretically given by the equation.

$$W = \frac{Q}{V} \cdot D$$

Where,

W: Effective width, in meter
Q: Pedestrian volume, person per minute
V: Walking velocity, in meter per minute
D: Space for one pedestrian, square meter per person.

The minimum width of footpath of pedestrian overpass shall be 1.5m, but 2.0m when bicycles, baby carriages and wheelchairs are expected to use the overpass (see Table 5.22).

b. Width of Stairway and Slopeway

The width of stairway and slopeway shall be at least 1.5m and 2.0m, respectively, and a minimum of 1.2m and 1.7m, respectively under very special conditions (see Table 5.22). As for the stairway with slope, the minimum width of a portion of slope shall be 0.6m as a standard.

Table 5.22 Width of Pedestrian Bridge

(Unit : meter)

Method for rise and fall	Minimum width of footpath	Minimum width of stairway or slopeway	
		rule	reduction
Stairway	1.5	1.5	1.2
Slopeway	2.0	2.0	1.7
Stairway with slope	2.0	2.1	1.8

c. Stairways

The gradient of stairway shall be 1:2 as a standard. Landing shall be provided at half way of stairway in the case that height is more than 3 meters.

5.8 Review of Technical Guidelines on Sign and Marking

A review was made on the "Manual on Traffic Control Devices" (hereinafter referred to as "Manual"), one of the technical standards that have been developed by DOH and are currently in use. The Manual consists of two parts, part 1 Traffic Signs and Part 2 Markings in which detailed description is found on their types and sizes, the location and method for installation.

Some recommendations are drawn through reviewing on each part of the Manual as seen in the following sections.

5.8.1 Traffic Signs

(1) Regulatory Signs

Although the Manual specifies the location for installation of each sign individually, repetitive usage of the sign at appropriate spacing should be considered when a certain control applies on zone basis such as maximum speed control in community zone.

In this application, supplemental Directional signs are effectively used together with the corresponding regulatory sign.

The spacing of regulatory signs should be decided taking into account various factors such as driving speed, drivers' behaviour and visivility of signs which depends largely on the situations of roads and its vicinity. However, it should be noted that excessive signs invite drivers' disrespect to them.

The standard spacing being practiced in Japan is shown in Table 5.23. The standard spacing seems to have been determined to be appricable even under less favorable circumstances in terms of visibility. Thus, when the better visibility along highways is maintained, it is appropriate to enlarge the standard spacings in Table 5.23.

(2) Warning Signs

Adequate warning signs provide vehicle operators with great assistance by noticing existing or potentially hazardous conditions, the use of which, however, should be carefully investigated and kept to a minimum because excessive installation often results in disrespect and depreciation of the signs themselves.

Table 5.23 Standard Spacing of Regulatory Signs

Type of Signs	Highway		Expressway
	Urban area	Rural area	
No-Passing	200 m	400 m	800 m
Maximum speed	200 m	400 m	800 m
Minimum speed	-	800 m	800 m
No stopping or standing	100 ~ 200 m	400 m	800 m
No-Parking	100 ~ 200 m	400 m	800 m
No crossing of Pedestrian			
- with guardfence	150 m	150 m	-
- without guardfence	100 m	100 m	-

1) Intersection Ahead Sign

Since the necessity of this warning sign is governed by the actual road or traffic conditions, it is recommended, more emphasis be given to those locations as shown below through deliberative field investigation besides the locations specified in the Manual in terms of highway type or traffic volume.

- When the existence of intersection or its traffic situation is not recognizable from highways with high speed vehicles or with short sight distance due to geometrical or road side condition.
- When Stop sign is not distinct at the approach of stop-controlled intersection.
- At hazardous intersections with high accident rate.

In this context, some intersections may not always require this sign when the existence of intersection is clearly recognizable such as at signalized intersections or the intersections where guide signs are installed properly.

2) Curve, Turn, Winding Road Signs

The prevailing speed at major DOH highways is quite high in general, reaching 80 - 85 Km/hr. The warrant for these signs in the Manual is

based on the recommended speed at a curve section, that is, 50 Km/hr or less (Turn sign) and 50 - 90 Km/hr (Curve sign), which seems to be established to accord with the above traffic situation.

The warrant, however, seems to result in too many Curve and Turn signs at curve sections of low standard highways having lower design speed such as those in mountainous area. In this situation, the signs are to be restricted to those locations where abrupt deceleration is required due to sharp change in the alignment as seen in Table 5.24.

At road having a series of curve section, Winding Road sign will be effectively applied with supplemental sign indicating the length of section where curves are especially concentrated. This will also be a necessary consideration for avoiding excessive installation of warning signs.

Table 5.24 Selection Criteria for Turn or Curve Sign

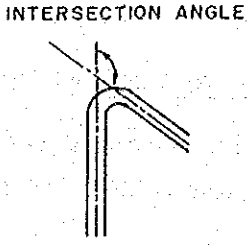
a. Prevailing approach speed 60km/hr or more

Curve Radius	Intersection Angle	Remarks
300m or more	0° - 180°	not necessary
60 - 300 m	0° - 180°	Curve
30 - 60 m	0° - 45°	Curve
	45° - 180°	Turn
Less than 30 m	0° - 180°	Turn

b. Prevailing approach speed about 40 km/hr

Curve Radius	Intersection Angle	Remarks
120 m	0° - 180°	not necessary
30 m - 120 m	0° - 180°	Curve
15 m - 30 m	0° - 60°	Curve
	60° - 180°	Turn
Less than 15 m	0° - 180°	Turn

Note ; Intersection angle shall conform to right-hand figure.



3) Advance distance

The manual prescribes the advance distance of warning signs, which varies from 100m up to 250m according to the type, whereas dominant distance is 200m - 250m.

These distances may also be applicable to fairly high approaching speed such as 80 km/hr or more. For the cases with lower approach speed, reduced advance distance of 60 - 100m is recommended. The value will be obtained from the formula in the following subsection.

(3) Guide Signs

1) Guide Signs at Intersection

Guide signs at intersection are commonly composed of Junction assembly, Destination and Direction sign and Direction assembly (National highway and Asian highway only) at each approach as seen in Figure 5.29. In this array, Route marker of Junction assembly seems to cause confusion of drivers about the route driving on and may not be necessary.

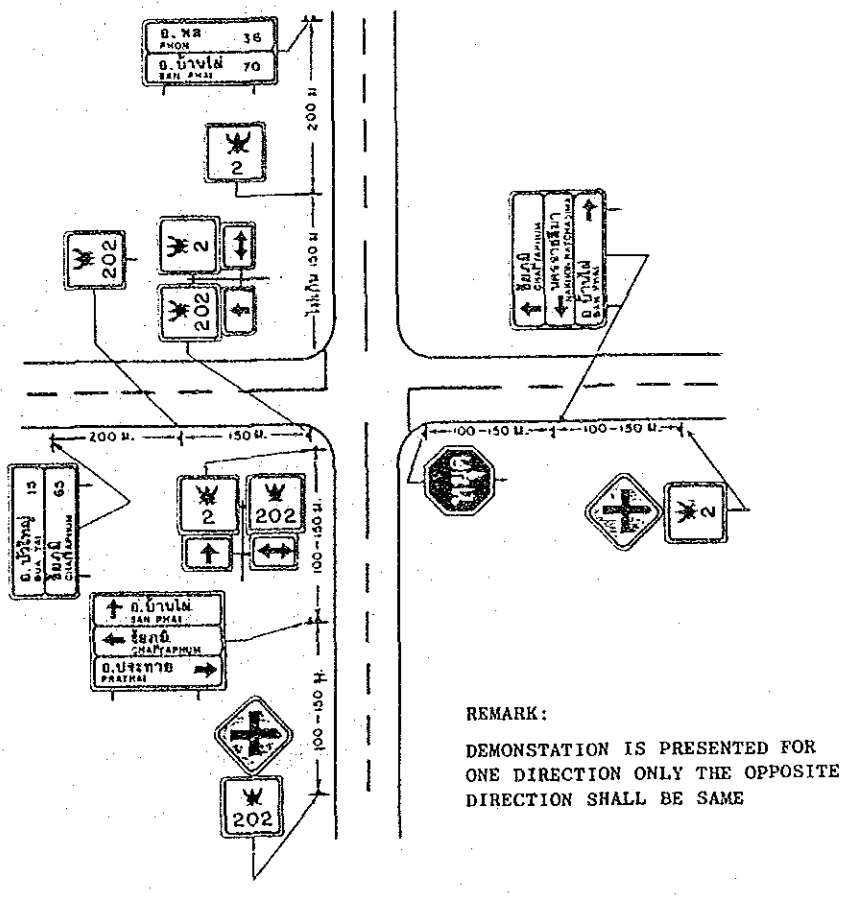
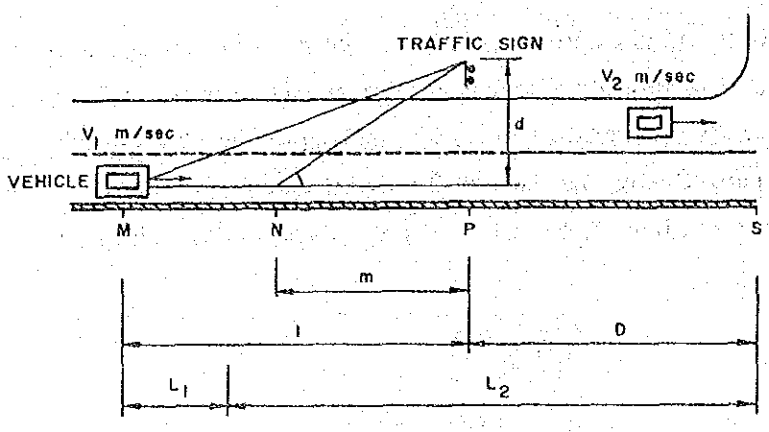


Figure 5.29 Array of Guide Signs at Intersection of National Highways

2) Advance Distance

Although the arrangement of guide signs at intersection seems to be in a uniform way as seen in Figure 5.29, some consideration on the advance distance will be required especially for Destination and Direction sign, the adequate location of which varies with the size of character and the vehicle approach speed.

In the following, a general method is introduced for calculating the advance distance of guide signs. Figure 5.30 illustrates the inter-relationship of vehicle, sign and intersection.



M : READING POINT (THE DRIVER FINISHES READING THE SIGN)
N : VANISHING POINT (THE SIGN VANISHES FROM THE DRIVER'S SIGHT)
P : SIGN LOCATION
S : INTERSECTION OR CORRESPONDING HAZARDOUS POINT
D : ADVANCE DISTANCE
d : TRANSVERSE DISTANCE OF SIGN BOARD (OUTER EDGE)
m : DISTANCE OF THE VANISHING POINT FROM THE SIGN
l : READING DISTANCE
L_1 : DISTANCE FOR PERCEPTION AND REACTION
L_2 : DISTANCE FOR CHANGING LANE AND REDUCING SPEED

Figure 5.30 Illustration of Sign Location

In this illustration, the following conditions should be satisfied for the driver to be able to maneuver the vehicle safely before the point S.

$$D + \ell \geqq L_1 + L_2 = 2.5\, V_1 + (n-1)\cdot V \cdot t + \frac{V_1^2 - V_2^2}{2\alpha} \qquad (1)$$

$$\ell \geqq m = d/\tan\theta \qquad (2)$$

where,

V_1 : prevailing speed (m/sec)
V_2 : speed at S (m/sec)
n : number of lanes
α : deceleration rate (1 - 2.5 m/sec^2)

In eq. (1), perception and reaction time is taken as 2.5 sec. and when applying for guide signs, the distance should be increased by about 30m for the glance reading of the sign. The distance required for a single lane change (second term in eq.(1)) may also be approximately 150m from the research* conducted in Japan.

In eq.(2), the angle is taken as 10 degree for horizontal angle and 7 degree for vertical angle when applied for overhead or overhang type signs.

The key value in eq.(1) lies in the reading distance which is also obtained as a function of the character type, letter height and moving speed, as follows;

$$\ell = \frac{20}{3} \cdot k \cdot R \cdot h \quad (h \leqq 45\ \text{cm}) \qquad (3)$$

where;

k: factor by the character

for alphabet k = 1.2
for Thai k = 0.8

R: dynamic legibility coefficient

R = 1.0 for V = 0 km/hour
= 0.91 V = 40 "
= 0.87 V = 60 "
= 0.82 V = 80 "

h: letter height (cm)

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* N. Kurimoto, T. Kaji "A Study on Methods of Allocation and Placements for Highway Guide Signs" Report of PWRI, Vol. 161-2, Feb. 1984.

The factor adopted for Thai character is estimated by comparing the research results on the legibility of Thai place-names conducted by Saraithong* and Hualthanom**.

(Example for Destination and Direction sign)

Conditions;

h = 25cm, V_1 = 80km/hr(22.2m/sec), V_2 = 20km/hr(5.6m/sec)

α = 1.5m/sec^2, n = 1, d = 10m

$$\ell = \frac{20}{3} \cdot 0.8 \cdot 0.82 \cdot 25 = 109.3 \text{ m}$$

$$D = L_1 + L_2 - \ell$$

$$= (2.5 \times 22.2 + 30) + \frac{(22.2)^2 - (5.6)^2}{2 \times 1.5} - 109.3$$

$$= 85.5 + 153.8 = 109.3 = \underline{130.0 \text{ m}}$$

$m = 10/\tan 10° = 56.7\text{m} < 109.3\text{m}$

5.8.2 Markings

(1) Longitudinal Markings

1) Width of Markings

The width of longitudinal markings is standardized to be 10 cm in general which is adequate for normal condition, but it will be effectively widened up to 20 cm where special attention of drivers should be called to form an orderly flow at hazardous road sections or intersections.

2) Outer Edge Line

Application of outer edge line is specified in the Manual in terms of number of lanes, width of carriageway and ADT. According to the volume survey results, two-lane road length which falls within the warrants accounts for approximately 15 percent of total national highways and few

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* P. Saraithong "Optimum Design of Thai-character Highway Signs" Thesis No. 163 SEATO Graduate School of Engineering, 1967.

** S. Hualthanom "Analysis of the effect of Duration of Exposure on Glance Legibility of Thai-character Highway Signs" Thesis, Asian Institute of Technology, 1968.

recommended at such locations as hazardous intersection approach regardless of ADT and road section where segregation of slow traffic or pedestrian is required.

(2) Markings at Intersection

1) Right-turn Lane Transition

The following formula, adopted in the Manual for calculating the length of converging lanes at pavement width transition section, will be applicable for obtaining suitable transition length to provide right-turn lane at intersection.

$$L = k \cdot V \cdot W$$

where,

L : Taper Length (m)

V : Prevailing or design speed (km/hr)

W : Width of transition (m)

k : Coefficient,
(0.6) for normal road section
(1/3-1/2) for approach of intersection
(1/6) for entrance of turning lane at intersection

2) Others

There are some controls in which markings are also recommended in addition to primary regulatory signs such as NO U-turn sign and Speed Limit signs.

Some other useful markings are shown below.

- Symbol marking to guide right turn vehicle at the center of intersection (See Fig. A9 in the Drawings)
- Symbol marking for advance notice of crosswalk (See Fig. A11, A19 in the Drawings)

Note: Diamond shape marking was proposed here to avoid confusion with the marking at Priority-crossing (Triangle shape) although the latter one is applied widely in Bangkok area as advance notice of crosswalk.

5.9 Others

5.9.1 Skid Resistance

(1) Survey of Slippery Road

Among the hazardous road sections which are selected by identification method and accident pattern analysis, the cause of accident at some of the road segments is found to be attributable to skidding of vehicle.

For determination of the slipperiness of the road surface, following reviews are generally to be made.

1) Wet Accident Ratio

The wet accident ratio is normally calculated by the following equation;

$$\text{Wet accident ratio} = \frac{\text{wet accident}}{\text{wet accident + dry accident}} \times 100\%$$

If this ratio is more than 30-50%, the cause of accident is considered to be the slipperiness of road surface.

2) Wet Skid Resistance Coefficient

If possible, it is recommended to measure wet skid resistance coefficient of road, and when the coefficient of friction is small (refer to following table), it will be decided that the cause of accident of this road segment is the slipperiness.

Table 5.25 Recommended Minimum Interim Skid Numbers (Proposed, H R B, U.S.A.)

Main traffic speed V (mph)	Skid number	
	SN^b	$SN_{40}c$
0	60	-
10	50	-
20	40	-
30	36	31
40	33	33
50	32	37
60	31	41
70	31	46
80	31	51

1. On the basis of measuring method of ASTM E-274
2. SN_b the measured value at mean traffic speed
3. SN_{40} is the measured value at 40 mph speed
4. Skid number is the 100 times of coefficient of skidding friction. This applies the same in others.

(2) Countermeasures

As countermeasures for skidding of road surface, there are several elements to be considered.

1) Binding materials

For both asphalt pavement and cement concrete pavement, the content of binding material (asphalt bitumen, portland cement) should be minimized. For the cement concrete pavement, cement content less than 300 kg/m^3 will be better and maximum 330 kg/m^3 will be recommended for skidding prevention. When more than 330 kg/m^3 will be used, it is advisable to test the degree of skidding before construction. For asphalt pavement, the use of asphalt shall be minimized within the limit of Marshall Stability Test.

It is also recommended to use the special binding materials (rubber-mixed asphalt, high molecular polymerized), if available.

2) Aggregate

Limestone and metamorphic rock are not good for skid resistance. Slag, sandstone, emery, silica sand are good for skid resistance.

3) Mixture

For anti-skid asphalt pavement, open graded asphalt concrete will be recommended.

Table 5.26 Mix Proportion of Aggregates for Open Graded Asphalt Concrete

		Open Graded Asphalt Concrete
Compacted Thickness (cm)		3 - 4
Max Particle Size (mm)		13
Weight percent passing sieve	25 mm	-
	20	100
	13	95 - 100
	5	23 - 45
	2.5	15 - 30
	0.6	8 - 20
	0.3	4 - 15
	0.15	4 - 10
	0.074	2 - 7
Asphalt Content (%)		3.5 - 5.5

4) Surface treatment

As for anti-skid surface treatment, following methods are recommended (1) to spread hard aggregates over the asphalt mixed layer and to compact (rolled asphalt), (2) to spread asphalt coated gravel over the asphalt mixed layer, (3) surface dressing; to spread epoxyresin 1.5 kg/m^2 (standard case) and spread aggregate (1.2 - 3.2 mm) 7 kg/m^2 over the epoxyresin.

These treatments are not only useful for anti-skid pavement, but also useful for speed control. These kinds of pavement generate about 3-5 dBA higher noise compared to dense graded asphalt concrete pavement. These pavements are useful at the intersection approach or curved section to control high running speed, as shown in Figure 5.31.

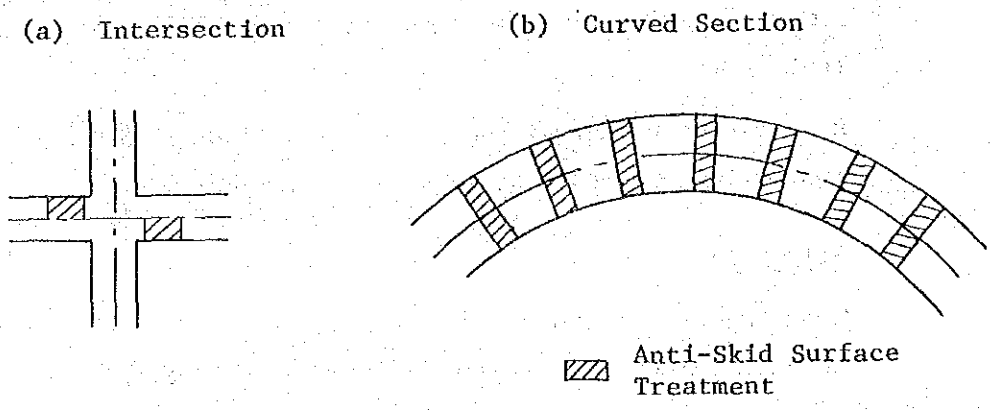

Figure 531 Application of Anti-Skid Surface Treatment

5) Grooving on the surface of pavement

Grooving method is also used for anti-skid purpose. This method is especially effective for hydroplaning on the high-speed highway. Nowadays, tine grooving method is also used as simple and cheap grooving. Tine grooving method is to scratch fresh concrete pavement surface with steel wire.

5.9.2 Evenness of Road Surface

(1) Longitudinal Evenness

Evenness of pavement surface is measured by means of roughness and profile. Roughness is used for riding quality. Profile is used for repair limit from the viewpoint of traffic safety. In Japan, limit of profiles is for express highway 90 mm/km (PrI) using 8m profilometer, and for arterial road 5.0 mm (σ) using 3m profilometer.

Vertical grade gap (for example approach to bridge) limitations are on express highway 10 - 30 mm, and on arterial road 15 - 40 mm.

(2) Rutting of Pavement

Rutting of pavement is measured by cross-sectional profile. In Japan, limit of rut depth is for express highway 25 mm, for arterial road 30 - 40 mm, and for other road 40 - 50 mm.

Chapter 6

TRAFFIC SAFETY PLANNING

Chapter 6 TRAFFIC SAFETY PLANNING

6.1 Process of Traffic Safety Planning

6.1.1 Introduction

The traffic accident problem is complex and can be arrested through implementation of comprehensive safety measures involving such parties as road users, traffic police and highway administrators. In view of this, a traffic safety plan by highway administrators should be prepared in close collaboration with concerned parties.

The traffic safety planning for engineering remedy works is to determine effective and realistic safety measures for hazardous road locations and to work out implementation programs including detailed designs and cost estimation. A traffic safety plan for a certain location is generally mapped out in the following sequence of steps:

- to select a location which needs for remedy works,
- to collect and analyze data and information pertaining to traffic accident,
- to clarify major accident causes and accident pattern,
- to determine safety measures applicable to the loca-tion, and
- to prepare implementation program

6.1.2 Process

(1) Selection of Location

It is general that the requests for safety improvement surpass the fund available for remedy works. To optimize the investment of limited fund, the selection of hazardous locations should be carried out in a way that high risk road locations are accorded with high priority.

It is, therefore, very desirable to formulate a medium term plan for a certain period of time (e.g. five years) based on sound engineering practices (see Chapter 8) and select priority locations within the framework of the medium term plan.

To select priority locations, preparation of accident location histograms (see Chapter 3) and application of the indentification method of hazardous location (see Chapter 4) would be of a great helpful means.

The hearing from district engineers, local police and people in community is also essential to grasp local demands.

To finalize locations for safety planning, the coordination among the concerned divisions at the headquarters of DOH is important to avoid duplication of investment.

(2) Collection and Analysis of Data

To plan out remedy works, accident data are prerequisite. The data at the headquarters can provide basic information as far as the roads where HPD is responsible for investigation are concerned. For the remaining roads, data collection by means of the way discussed in Chapter 3 is necessary.

As for road conditions, available information is very limited and thus field investigation either by staff of district offices or headquarters should be undertaken to get information as to the performance of pavement, alignment, existing safety devices, land use in the vicinity of road, etc.

The obtained data and information should be thoroughly analized so as to pinpoint a hazardous location, to grasp features of accidents and major causes of accident, and possibly to find deficiencies in road conditions if any.

(3) Clarification of Major Accident Causes and Accident Pattern

The traffic accidents are phenomena resulting from complex causes. But there are some accidents of which causes are not attributable to road conditions. When hazardous locations for safety planning are selected, thorough analyses on the data of accidents at the locations should be made to clarify the accidents' causes and to see whether engineering remedy works are workable.

The analyses can be conducted using accident records, collision diagrams, location maps and road conditions, and will clarify the major causes of accidents at the locations.

Although traffic accident is an incidental phenomenon and should be prevented through countermeasure specific to the accident site, there are common relations, to a large extent, between accident patterns and effective

countermeasures. The relations are presented in the next sub-section of "Guideline for Traffic Safety Planning".

The traffic accidents can be classified into a set of accident patterns shown in Table 6.1, and then possible countermeasures for the classified accident patterns can be found in the above guideline.

Table 6.1 Comparison of "Accident Patterns" and Collision Diagram Code by DOH

Accident Pattern	Collision Diagram Code (DOH)
10. Vehicle vs. Pedestrian	
11. Hit pedestrian walking along carriageway	05,06
12. Hit pedestrian crossing carriageway at intersection	07
13. Hit pedestrian crossing carriageway at crosswalk	09
14. Hit pedestrian crossing carriageway other than crosswalk	01,03
15. Hit pedestrian emerging on carriageway	02
16. Hit pedestrian playing on carriageway	04
17. Others	08
20. Vehicle vs. Bicycle	
21. Head on collision	19
22. Rear end collision	11
23. Side collision during crossing	12
24. Side collision during right turn	13,16
25. Side collision during left turn	-
26. Others	14,15,17,18
30. Vehicle only	
31. Off carriageway	71,72,73,74,75,76,78, 81,82,83,84,86,87
32. Collision with parked vehicle	52,53,54
33. Collision with guard rail	55,56,79
34. Collision with electric pole	-
35. Collision with other objects	48,57,58
36. Others	59,91,92,93,94,95
40. Vehicle vs. Vehicle	
41. Head on collision	36,46,61,77,85,88
42. Rear end collision	33,35,37,38,51
43. Side collision during crossing	21,22,23,29,44
44. Side collision during right turn	24,25,26,31,32,41
45. Side collision during left turn	27,28,34
46. Side contact	42,43,47
47. Others	62,63,64,65,66,89
50. Unknown	96

* See Appendix 3.1

(4) Determination of Safety Measures

There are a number of alternative measures applicable to a given location as shown in the guideline. The safety measures should be finalized selecting the most suitable one or combination of some alternatives among the possible alternatives, taking into account the existing safety devices at the location, traffic regulation, traffic characteristics and road conditions as well as available funds. The technical guideline on the safety devices presented in Chapter 5 of this report also should be referred to.

(5) Preparation of Implementation Program

Detailed designs for the finalized safety measures shall be prepared in a way that the safety devices installed at the location will fully realize the intended function in the safety measures.

6.2 Guideline for Traffic Safety Planning

6.2.1 Introduction

Traffic accidents are generally phenomena accrued from multicauses specific to them and thus engineering safety plans to prevent accidents shall be prepared based on detailed analyses and thorough field investigations at each accident site.

From the studies on the past experiences of traffic accidents, it is a well-known fact that there are relations, to some extent, between accident patterns and accident causes. The relations become more obvious when discussed by road type.

This enables highway engineers to work out a set of traffic safety plans by accident pattern and road type. The set of plans is expected to be a very useful means, providing engineers with basic information to prepare an actual and effective safety plan at a given road site.

In this chapter, a set of traffic safety plans (this may reasonably be called as "guideline for traffic safety planning) has been prepared by road types as classified in Figure 6.1. The details of the guidelines for roadway and intersection are presented in the following sub-sections of 6.2.2 and 6.2.3, respectively.

It should be stressed that the guideline in this report is of a general standard and presents various alternatives, and a final safety plan for action should be made taking into account various factors such as road conditions, warrants of safety devices and economic aspects.

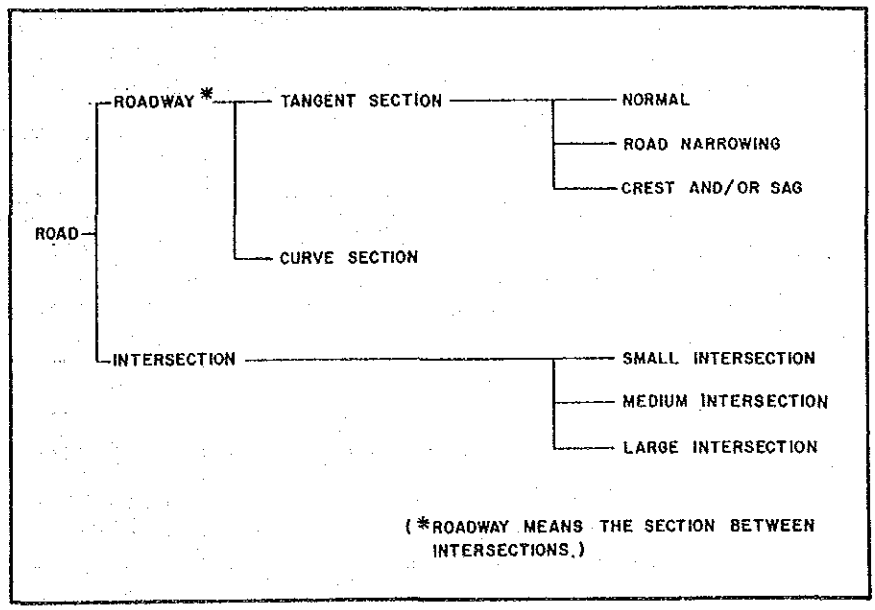

Figure 6.1 Road Classification by Type

Additionally, it should be kept in mind that the various safety measures discussed in the following sections are only effective when the traffic regulations are strictly practiced and observed by all road users.

6.2.2 Roadway

(1) Roadway; Tangent/Normal

Typical accident patterns at normal section on tangent roadway are;

- Off-carriageway accident;
- Head-on collision;
- Rear-end collision; and
- Pedestrian accident.

The major safety measures to cope with above-mentioned accident patterns are described below, by main causes for each accident pattern.

1) Off-Carriageway Accident

Table 6.2 shows safety measures and safety devices by major causes of off-carriageway accidents at normal section on tangent roadway.

Table 6.2 Safety Measures for Off-Carriageway Accident on Roadway; Tangent/Normal

Causes of Accident	Safety Measures	Safety Devices
Excessive speeding	Limitation of running speed	Regulatory sign Pavement marking
Disorderly traffic flow	Ensurance of orderly traffic flow	Lane marking Delineator
Slippery and irregular surface	Treatment of surface	Skid resistant pavement Patching
-	Prevention of serious accident	Guardfence Improvement of shoulder

Excessive speeding

Driving at excessively high speed reduces the driver's capability to react to the sudden appearance of obstructions and changing condition, and often it causes losing control of steering. Regulatory sign and/or inscription marking on the pavement indicating safe driving speed under the prevailing conditions are generally effective.

Disorderly traffic flow

Lane markings, especially edge lines, are very important to maintain an orderly traffic flow channelizing vehicles into lanes, and lateral guidance like delineators and ridding carriageway of obstacles likes illegal parking cars are necessary.

Prevention of serious accident

From the viewpoint of mitigating severity of off-carriageway accidents installation of guardfence at shoulder to protect vehicles from running into hazardous road sides, or median to block vehicles from running to opposite lanes should be considered. From the same aspect, improvement of weak shoulder in structure is also desirable. However, as guardfence and medians turn to hazards, careful studies are required prior to installation of them.

2) Head-on Collision

Safety measures and devices by major causes of head-on collision at normal section on tangent roadway are shown in Table 6.3.

Table 6.3 Safety Measures for Head-on Collision on Roadway; Tangent/Normal

Causes of Accident	Safety Measures	Safety Devices
Improper Overtaking	Restriction of overtaking	Regulatory sign Continuous center line Raised pavement marks Median
Excessive Speeding	Limitation of running speed	Regulatory sign Pavement marking

Improper overtaking

Where it is difficult to ensure sufficient distance for overtaking safely because of high traffic volume and/or steady traffic flow on the opposite lane, prohibition of overtaking should be considered by regulatory signs and continuous center line, and a series of raised pavement markers if necessary. For the road 4 or more than 4-lane carriageway, median is desirable.

Excessive speeding

Vehicles with excessive speed are liable to lose steering control because of sudden reaction to the movements of other vehicles, pedestrian, bicycle, entering vehicle from road side, obstruction, etc. And vehicles often stride over the center line and cause the head-on collision. Therefore, it should be considered to restrict the excessive speeding. Regulatory signs and inscription marking on the pavement indicating safe driving speed under the prevailing conditions are generally effective.

3) Rear-end Collision

Table 6.4 shows safety measures and safety devices by major causes of rear-end collision at normal section on tangent roadway.

Interruption of smooth traffic flow

Sudden braking due to an interruption to the smooth traffic flow causes a rear-end collision. These interruptions are caused by the improper movements of pedestrians, bicycles and buses, parked vehicles and obstructions, hence safety measures should be prepared after finding major causes of the interruptions.

For the problems relating to pedestrians and bicycles, edge line, sidewalk and bicycle path to separate them from vehicular traffic or crossing facilities such as crosswalk, crosswalk with traffic signals and pedestrian overpass are generally effective safety measures.

Separation of pedestrian and bicycles by edge line will in most cases require the improvement of shoulder such as surface treatment.

Type of crossing facilities should be selected taking into account the volume of vehicular traffic and pedestrian (for details see Chapter 5).

Table 6.4 Safety Measures for Rear-end Collision on Roadway; Tangent/Normal

Causes of Accident	Safety Measures	Safety Devices
Interruption of smooth traffic flow	Separation of pedestrian and bicycle from vehicular traffic	Edge line Sidewalk Bicycle path
	Prevention of crossing by pedestrians	Crosswalk Crosswalk with traffic signal Pedestrian overpass Warning sign Guardfence
	Restriction of parking Separation of slower speed vehicles in congested area	Regulatory sign Marking on curbs Edge line Bus bay Frontage road
Disorderly traffic flow	Ensurance of traffic flow	Lane marking Guide sign
Improper Overtaking	Restriction of overtaking	Regulatory sign Continuous center line Raised pavement marks Median

Additionally, installation of advance warning signs and inscription markings on the pavement are essential for crosswalk. In the urban area, sidewalk guardfence to prevent pedestrians from random crossing and jaywalking is applicable too.

Regarding the problem of parking vehicles, edge line and restriction of parking are effective.

In some commercialized or densely populated areas, there are sometimes confused traffic flows caused by the movements of variety of traffics and parked vehicles. In these areas, provision of bus-bay and/or frontage road

along the arterial road to separate the slower speed vehicles, buses and vehicles related to commercial area could be one of solutions.

Disorderly traffic flow

Lane markings, especially edge line, are very important to ensure orderly traffic flow channelizing vehicles into lanes. Guide sign is also useful for turning vehicles to change the lane smoothly.

Improper overtaking

Improper overtaking will force sudden stopping of overtaken vehicles and vehicles driving on opposite lane and it causes rear-end collision. Therefore, in the section where it is difficult to ensure the sufficient distance for overtaking safety because of high traffic volume and/or continuous traffic flow on the opposite lane, overtaking should be prohibited and regulatory signs, continuous center line, and series of raised pavement markers, if necessary, should be placed. For more than 4-line road, median is desirable.

4) Pedestrian Accident

Typical patterns of pedestrian accidents are collision with vehicles when walking along roadside and crossing other parts than crosswalk. Table 6.5 shows safety measures and devices by major causes of pedestrian accident at normal section on tangent roadway.

Table 6.5 Safety Measures for Pedestrian Accident on Roadway; Tangent/Normal

Causes of Accident	Safety Measures	Safety Devices
Random crossing on road	Provision of crossing facilities	Crosswalk Crosswalk with traffic signal Pedestrian overpass Warning sign Guardfence Lighting
Walking on Carriageway	Separation of pedestrian	Edge line Sidewalk

Random crossing on road

Crossing facilities are effective to ensure the safety of pedestrian as well as smooth traffic flow, since these facilities can prevent pedestrians' random crossings on road and drivers can expect the existence of pedestrians at fixed points and give sufficient attentions to them.

As to crossing facilities, there are various types like crosswalk, crosswalk with traffic signal and pedestrian overpass. Selection of crossing facilities should be carried out taking into account the volume of vehicular traffic and pedestrian (for details see Chapter 5).

It should be noted that series of advance warning such as signs and inscription markings on the pavement (see Figure 6.2), and restriction of parking in the vicinity of the crossing facilities are essential. At the section where many accidents are recorded at night, lighting is desirable too.

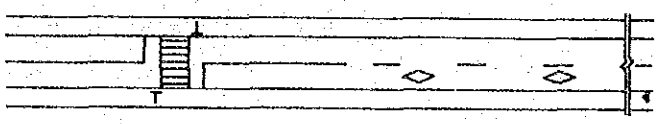

Figure 6.2 Crosswalk

Jaywalking on the carriageway

Sidewalk is effective to reduce the conflict between vehicular traffic and pedestrian jaywalking on roadway. Edge line is also useful in the section where pedestrian volume is relatively low.

In the densely populated area, provision of guardfence can be considered to ensure the safety of pedestrian and prevent random crossings on road and jaywalking on carriageway.

(2) Roadway;Tangent/Narrowing

Typical accident patterns at narrowing sections on tangent roadway such as approach to a bridge and a changing point of lane number are;

- Off-carriageway accident; and
- Rear-end collision.

The major safety measures to cope with above-mentioned accident patterns are described in Table 6.6.

Table 6.6 Safety Measures for Off-Carriageway Accident and Rear-end Collision on Roadway; Tangent/Narrowing

Causes of Accident	Safety Measures	Safety Devices
Sudden narrowing	Information of road condition	Warning sign Lighting
	Provision of visual guidance	Lane marking Delineator
	Ensurance of length for lane shifting	Lane marking
Improper merging	Clarifying the priority of lane	Pavement marking
Improper overtaking	Restriction of overtaking	Regulatory sign Continuous center line

Above-mentioned accident patterns have common causes. They are sudden changes of width of shoulder and/or carriageway, improper merging or improper overtaking.

Sudden change of width

At the section where the width of carriageway and/or shoulder become narrow, especially at the end of the monotonous horizontal alignment section, there are frequent collisions and off-carriageway accidents caused by sudden braking or abrupt lane shifting.

To cope with above-mentioned problems, it is important to inform drivers of existence of narrowing road, in advance, by sign and to provide the visual guidance such as edge line and delineator. Provision of sufficient transition length at the sections is also necessary for the smooth lane shifting.

Improper merging

At the section where lane number changes, drivers are liable to fail to appreciate priority of right of the way. Clarifying the priority lane by such pavement markings as painted stripe on the less-priority lane and directing arrow are effective for smooth merging and accident prevention.

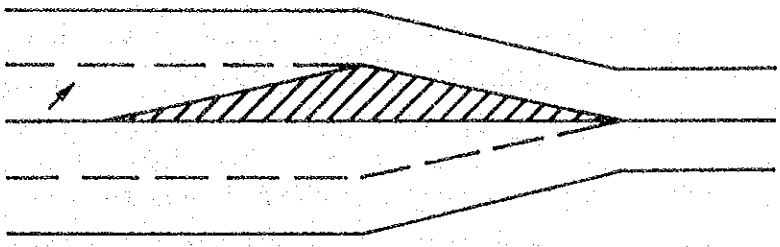

Figure 6.3 Marking for Road Narrowing

Lighting can be considered at the section with heavy traffic volume, if necessary.

Improper overtaking

Overtaking at narrowing road section should be restricted by means of continuous centerline and regulatory sign.

(3) Roadway; Tangent/Crest, Sag

Typical accident patterns at crest and sag sections on tangent roadway are;

- Off-carriageway accident; and
- Head-on collision.

The major safety measures to cope with these accident patterns are described below.

1) Off-Carriageway Accident

Safety measures and devices by major causes of off-carriageway at crest and sag section on tangent roadway are shown in Table 6.7.

Table 6.7 Safety Measures for Off-Carriageway Accident on Roadway; Tangent/Crest or Sag

Causes of Accident	Safety Measures	Safety Devices
Excessive speeding	Provision of visual guidance	Lane marking
	Limitation of running speed	Regulatory sign
	Information of road condition	Pavement marking
		Warning sign
-	Prevention of serious accident	Guardfence
		Improvement of shoulder

The main cause of this titled accident pattern is an excessive speeding on downgrade section. Speed of vehicles is accelerated on the downgrades, and as a result, vehicles tend to exceed the safe speed.

The excessive speeding often leads to lost steering control. The crest/sag sections cause more hazards coupled with the restricted sight distance at the crest of vertical curves.

In order to prevent accidents, it should be considered to warn drivers of the existence of steep grade section, and to restrict driving speed, by means of regulatory sign and inscription marking. Lane markings are also essential as a mean of clarifying the edge of carriageway and optical guiding. Installation of guardfence to prevent serious accidents connecting with off-carriageway accident should be considered at the longer, steep downgrade section and the high embankment section. Improvement of weak shoulder is also desirable.

2) Head-on Collision

Table 6.8 shows safety measure and devices by major causes of head-on collision at crest and sag section on tangent roadway.

Table 6.8 Safety Measures for Head-on Collision on Roadway; Tangent/Crest, Sag

Causes of Accident	Safety Measures	Safety Devices
Improper overtaking	Restriction of overtaking	Regulatory sign Continuous center line Raised pavement marks Median
Excessive speeding	Limitation of running speed Information of road condition	Regulatory sign Pavement marking Warning sign

Improper overtaking

Most of head-on collisions at crests and sags of vertical curvature sections are caused by geometric lack of sight distance. The hazards at these sections are amplified when horizontal alignments are of curvature.

At these sections, strict prohibition of overtaking by means of regulatory sign, continuous centerline and series of raised pavement markers (if necessary) prove efficient. For more than 4-lane road, median is desirable.

Excessive speeding

Vehicle speed is liable to be faster on downgrade section. Excessive speeding leads to poor steering and often causes the head-on collision at or in the vicinity of crests and sags of curvature sections.

Hence, at the above-mentioned section, limitation of speed by means of regulatory signs and inscription marking on the pavement is effective.

(4) Roadway; Curve

Typical accident patterns at curvature sections on roadway are;

- Off-carriageway
- Head-on collision

The major safety measures to cope with these accident patterns are described below.

1) Off-Carriageway Accident

Safety measures and devices by major causes of off-carriageway accident at curvature section roadway are described in Table 6.9.

Table 6.9 Safety Measures for Off-Carriageway Accident on Roadway; Curve

Causes of Accident	Safety Measures	Safety Devices
Excessive speeding	Limitation of running speed Information of road condition Treatment of superelevation	Regulatory sign Pavement marking Warning sign Lighting
Restricted sight distance	Provision of optical guidance	Lane marking Delineator Reflective raised pavement mark
Slippery surface	Treatment of surface	Skid resistant pavement
–	Prevention of serious accident	Guardfence

Excessive speeding

At the sharp curve section, off-carriageway accidents are experienced frequently, especially at the sharp curve section which is located at the end of long tangent section, since driving on straight roadway for long periods of time often results in reducing perception of speed and diminishing the capability to react to sudden change of conditions.

Safe speed for steady driving on curvature section depends on curvature radius, degree of superelevation and coefficient of friction.

Therefore, it is important to inform drivers of the existence of sharply curved horizontal alignment so as to drive at safer speed. Limitation of speed is necessary at substandard curvature sections by means of regulatory sign and inscription markings on pavement. An adequate superelevation is also essential. Advance warning sign and lighting (if necessary) are effective too.

Restricted sight distance

Where sight distance is insufficient, optical guidance is essential to ensure the steady and safe driving. As for optical guidance, lane marking, delineator and reflective raised pavement marker are effective devices.

Slippery surface

At the section where many accidents occurred in rainy days, introduction of skid resistant pavement should be considered.

Installation of guardfence to reduce severity of off-carriageway accident should be considered at a sharp curvature section, when areas alongside road are very hazardous, and improvement of weak shoulder in structure is desirable too from the same point of view.

2) Head-on Collision

Table 6.10 shows safety measures and devices by major causes of head-on collision at curvature section on roadway.

Running onto opposite lane

Drivers tend to select larger radius path at a sharp curvature section, and as a result, they stride over the center line. This often leads to head-on

Table 6.10 Safety Measures for Head-on Collision on Roadway; Curve

Causes of Accident	Safety Measures	Safety Devices
Encroaching on opposite lane	Prohibition of encroaching on opposite lane	Regulatory sign Continuous center line Raised pavement mark Painted strip Median

collision. Therefore, at the sharp curvature section having a certain traffic volume, prevention of striding over the center line by means of continuous center line, raised pavement marker and painted strip at the center of carriageway should be considered. For more than 4-lane road, provision of median is desirable.

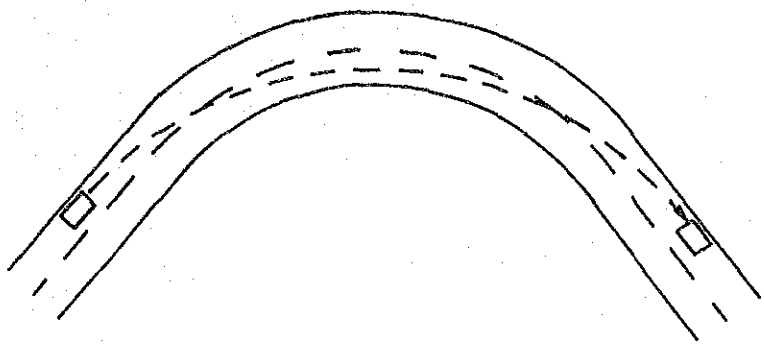

Figure 6.4 Encroaching on Opposite Lane

6.2.3 Intersection

(1) Small Intersection

T-shape intersections are predominant in the category of the small intersections and typical accident patterns at the intersections are;

- Side collision during turning; and
- Rear-end collision

The factors causing both accident patterns are very similar and they are, i) failure to yield right of way, ii) restricted sight distance, and iii) confusion due to turning vehicles. The major safety measures to solve above-mentioned problems are described in Table 6.11.

Table 6.11 Safety Measures for Side Collision during Turning and Rear-end Collision at Small Intersection

Causes of Accident	Safety Measures	Safety Devices
Failure to yield right of way	Clarifying the priority	Stop sign Stop line
Restricted sight distance	Improvement of sight distance	Corner cut
	Restriction of parking	Regulatory sign Marking on curb
	Indication of interseciton	Warning sign Inscription marking Lane marking
Confusion due to turning vehicle	Restriction of right-turn	Regulatory sign
	Access control	Regulatory sign Median Frontage road

Failure to yield right of way

Since many accidents are experienced at small intersections, stop sign and stop line should be placed on minor road to clarify the priority, because drivers approaching to major road often fail to yield right of way.

Restricted sight distance

Since potential hazard is increased by restricted sight distance, it is important to ensure necessary sight distance into main road at the

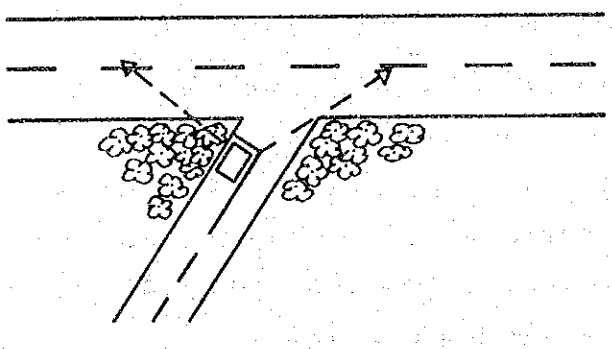

Figure 6.5 Restricted Sight Distance

location of stop line and to inform drivers of traffic conditions on road by means of corner cut, restriction of parking and improvement of gradient at the approach section of minor road (see Figure 6.5). While, it is also necessary to warn drivers on main road of the existence of intersection by means of advance warning sign, indication marking of intersection and lane marking.

Confusion due to turning vehicle

Where there is heavy traffic volume on main road, restriction of right-turn of vehicles on minor road should be considered.

In the section in urban area where there are many lower standard minor roads cross main road within short distances, restriction of right-turn and access control are effective to reduce the conflict point. The regulatory sign, mediam and frontage road are also effective means.

(2) Medium Intersection

Typical accident patterns at medium intersection are;

- Rear-end collision;
- Side collision during turning; and
- Pedestrians collision

The major safety measures to cope with above mentioned accident patterns are described below.

1) Rear-end Collision

Table 6.12 shows safety measures and devices by major causes of rear-end collision at medium intersection.

Confusion due to turning vehicles

Confusions are caused by conflicts between through vehicles and vehicles changing direction. In order to cope with this problem, separation of conflicting traffic streams is important.

Provision of turning lane, especially exclusive right turning lane is effective (see Figure 6.6). To make more effective, lane marking and series of directional arrows are essential, while guide sign and advance

Table 6.12 Safety Measures for Rear-end Collision at Medium Intersection

Causes of Accident	Safety Measures	Safety Devices
Confusion due to turning vehicles	Channelization	Lane marking Right turning lane Left turning lane Channelizing island Directional arrows Guide sign Advance warning sign Warning sign for obstruction Painted and/or raised strip
Interruption by parked vehicles	Restriction of parking	Regulatory sign Marking on the curb
Slipperly surface	Surface treatment	Skid resistant pavement
Interruption by Pedestrian	Limitation of improper movement	Crosswalk Sidewalk Guardfence Signal

warning sign of intersection are also necessary to avoid the confusion and sudden lane shifting. Right turning lane should be formed by island at the center to separate right turning vehicles from through traffic flow and to protect them from other vehicles.

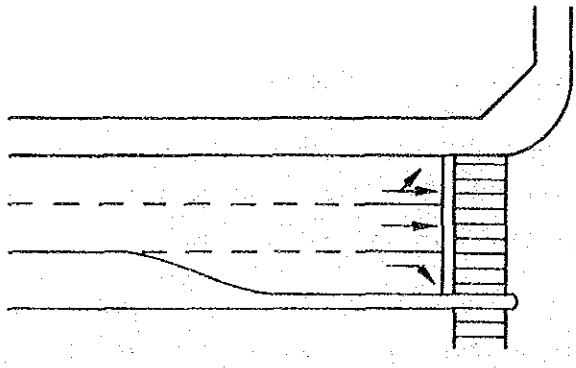

Figure 6.6 Right Turn Lane

Since the tips of island are dangerous obstacles for vehicles, provision of clear lane marking, warning sign for obstacle and shevron marking (or raised strip) should be considered, so as to inform drivers of the existence of islands.

2) Side Collision during Turning

Table 6.13 shows safety measures and devices by major causes of side collision during turning at medium intersection.

Table 6.13 Safety Measures for Side Collision during Turning at Medium Intersection

Causes of Accident	Safety Measures	Safety Devices
Failure to yield right of way	Clarifying the priority Channelization	Stop line Stop sign Right turning lane Left turning lane
Heavy traffic volume	Control of traffic	Traffic signal
Restricted sight distance	Improvement of sight distance Restriction of parking Information of road condition	Corner cut Regulatory sign Marking on the curb Warning sign

Failure to yield right

At the intersection without traffic signal control, it is important to clarify the priority by means of stop line and stop sign. Provision of turning lane is effective not only to provide the waiting space but to ensure the orderly traffic flow.

Heavy traffic volume

Where traffic volume is heavy, it is not easy to get the chance to make turning and this situation lead to reckless turning. At such intersection, installation of traffic signal should be considered. In the case, where there are many right turning vehicles, provision of exclusive phase of signal for right turning is desirable.

Restricted sight distance

Since there are many conflict points on the path of right turning, sufficient visibility should be ensured by means of corner cut, restriction of parking and installation of lighting (if necessary). Advance warning sign should be installed ahead of the intersection.

3) Side Collision during Crossing

Table 6.14 shows safety measures and devices by major causes of side collision during crossing at medium intersection.

Table 6.14 Safety Measures for Side Collision during Crossing at Medium Intersection

Causes of Accident	Safety Measures	Safety Devices
Failure to yeild right of way	Clarifying the priority	Stop line Stop sing
Heavy traffic	Control of traffic	Traffic signal
Restricted sight distance	Improvement of sight distance Restriction of parking Information of road condition	Corner cut Regulatory sign Marking on curb Warning sign

Failure to yield right of way

At the intersection without traffic signal control, stop sign and stop line on the minor road to clarify the priority are effective.

Heavy traffic volume

Where traffic volume is heavy, it is not easy to get the chance to cross the road and often causes a reckless crossing. Therefore, installation of traffic signal should be considered, taking into account the traffic volume on roads.

Restricted sight distance

Where the sight distance is restricted by parked vehicles and/or obstruction at the corner, restriction of parking and corner cut should be considered. Advance warning sign should be installed.

4) Pedestrian Accident

Table 6.15 shows safety measures an devices by major causes of pedestrian accident at medium intersection.

Table 6.15 Safety Measures for Pedestrian Accident at Medium Intersection

Causes of Accident	Safety Measures	Safety Devices
Random crossing	Provision of crossing facilities	Crosswalk Lighting Bicycle crossing signal
	Prevention of random crossing	Guardfence
Walking on Carriageway	Separation of pedestrian	Edge line Sidewalk Guardfence

Random crossing on the road

At the intersection in densely populated area, there are many pedestrians crossing on the roads at random to interrupt traffic streams. Therefore, it is important to provide the crosswalk at such intersections. And also guardfence to prevent the random crossing, the lighting and signal are desirable. Bicycle crossing is also effective at the intersection to separate bicycles from vehicular traffic flow.

Jaywalking on the carriageway

At the intersection where there are many pedestrians, edge line and/or sidewalk are essential to separate pedestrians from vehicular traffic. At the corner, installation of guardfence are desirable to ensure the safety of pedestrian.

(3) Large Intersection

Typical accident patterns at large intersection are;

- Rear-end collision;
- Side collision during turning;
- Pedestrian collision

The major safety measures to cope with above mentioned accident pattern are described below. Presented in the following sections are relatively easy remedy works which are immediately applicable to the existing intersections. The large scale improvement works such as grade separation, and introduction of round about should be discussed separately on case by case basis.

Although traffic signal control is essential and its installation should be given high priority to prepare safety plan at the intersection at a large at-grade intersection, it is not discussed in detail in this section, detailed information can be found in Chapter 5 of this report.

1) Rear-end collision

Table 6.16 shows safety measures and safety devices by major causes of rear-end collision at large intersection.

Table 6.16 Safety Measures for Rear-end Collision at Large Intersection

Causes of Accident	Safety Measures	Safety Devices
Confusion due to turning vehicles	Channelization	Lane marking Right turning lane Left turning lane Channelizing island, Median Directional arrows Guide sign Advance warning sign Warning sign for obstruction Painted and/or raised strip
Interruption by parked vehicles	Restriction of parking	Regulatory sign Marking on the curb
Slipperly surface	Surface treatment	Skid resistant pavement
Interruption by pedestrian	Limitation of improper movement	Crosswalk Sidewalk Guardfence Signal

Confusion due to turning vehicles

Provision of exclusive turning lanes, especially exclusive right turning lane is effective at large intersection. In general, these turning lanes are formed by islands such as triangular island and island at center. These islands have the functions of separation of traffic streams, protection of turning vehicles and protection of pedestrians as refuge island.

To make more effective, lane markings and series of directional arrows are essential in order to channelize the vehicles into the lane, and guide sign and advance warning sign of intersection are also necessary to avoid the confusion caused by sudden lane shifting and improper weaving.

It should be noted that since the tips of island are a dangerous obstacle for vehicles, lane marking, warning sign and shevron marking (or raised strip) should be installed in a proper manner.

Other factors

Restriction of parking is essential to avoid the confusion and ensure the traffic capacity by means of regulatory sign and marking on curb.

At the approach section where many rear-end collisions are recorded in rainy days, introduction of skid resistant pavement should be considered. Where many pedestrians cross the road and walk along the road, provision of facilities for pedestrians such as crosswalk, sidewalk, signal and guardfence (if necessary) should be considered.

2) Side collision

Table 6.17 shows safety measures and devices by major causes of side collision during turning at large intersection.

Table 6.17 Safety Measures for Side Collision during Turning at Large Intersection

Causes of Accident	Safety Measures	Safety Devices
Heavy traffic volume	Control of traffic	Traffic signal
Disorderly movement	Channelization	Right turning lane Left turning lane Channelizing island Lane marking Directional arrow Guide sign Indication marking of center intersection

Heavy traffic volume

Since at the large intersection, both crossing roads have heavy traffic volume and volume of turning vehicles are also high, traffic signals should be installed to ensure the safe and smooth traffic flows.

Disorderly traffic movement

At a large intersection where wide roads (more than four lanes) cross without proper channelization, an excessive pavement space can be found sometimes. This causes unnecessary increase of potential conflicts due to disorderly movements of vehicles in the intersection. Therefore, it is effective to ensure the orderly traffic movement by channelization.

Some methods of channelization are to provide right and/or left turning lane, island, guide lane and indication marking at the middle part of intersection.

Guide lane and indication marking are not familiar in Thailand but they are effective to channelize the right turning vehicles (see Figure 6.7). Guide lane is the extension of right turning lane into intersecting point by means of broken line, and its functions are indication of the turning path and waiting place. The function of indication marking at the middle part of intersection is to demarcate turning path for the right turning streams in opposite directions. The installation of lane marking, series of directional arrows, guide sign and advance warning sign of intersection also contribute to orderly traffic flow.

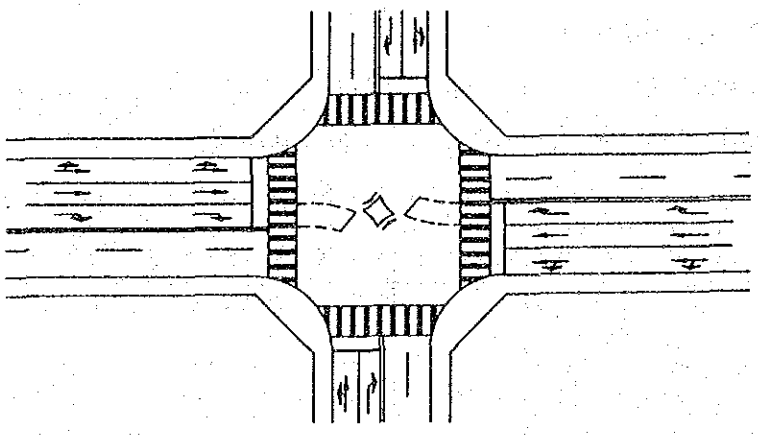

Figure 6.7 Guide Lane and Indication Marking

3) Pedestrian Accident

Table 6.18 shows safety measure and devices by major causes of pedestrian accident at large intersection.

Table 6.18 Safety Measures for Pedestrian Accident at Large Intersection

Causes of Accident	Safety Measures	Safety Devices
Random crossing	Provision of crossing facilities	Crosswalk Signal for pedestrian Pedestrian overpass Bicycle crossing Lighting Signal
	Prevention of random crossing	Guardfence
Walking on Carriageway	Separation of pedestrian	Edge line Sidewalk Guardfence

Random crossing

At the intersection in densely populated area, there are many pedestrian crossings, while traffic movements are very complicated at the intersection.

Therefore, it is important to provide crosswalks at the above mentioned large intersection and bicycle crossing also effective at the intersection when the volume of bicycles is high.

Signal for pedestrian is definitely effective for safer crossing. Guardfence to prevent the random crossing and the lighting are desirable at densely populated area.

If there are many lanes and many turning vehicles, pedestrian overpass should be considered.

Jaywalking on the carriageway

Where there are many pedestrians, edge line and sidewalk is essential to separate them from vehicular traffic. At the corner, installation of guardfence are desirable to ensure the safety of pedestrian.

6.3 Traffic Safety Plan for Study Road

6.3.1 Introduction

This section presents the result of the case study - safety planning on the Study Road applying a set of traffic safety measures in the "Guideline for the Traffic Safety Planning" formulated in the previous section 6.2.

The planning sections on the Study Roads have been selected in a way that at least, one of the safety measures for all accident patterns (see Table 6.1) could be incorporated in the case study.

The supplementary data for the safety planning have been collected jointly by DOH and the Team.

6.3.2 Selection of Safety Planning Sections

Total length of 41.4 Km (17 locations) out of 11 routes was selected from the Study Roads.*

The criteria for selecting "Safety Planning Sections" are established through a series of field surveys and the discussions with the staff of DOH. The adopted criteria are:

- high frequence of accidents;
- sub-standard alignments and disorderly traffic flow; and
- concerns expressed by relevant parties.

(1) Selection by High-Frequency Accident Criterion

The selection of safety planning sections by this criterion, required the tabulation of the accidents occurred during 1981 and 1982.

Firstly, the Study Roads (316 Km) were divided into one-kilometre long sub-sections and resulting 316 "records" were created. The records were, then, ordered by the total number of accidents: and thirty sub-sections with higher accident records are shown in Table 6.19. The sub-sections were combined, with reference to route number and kilo-post, into several continuous "road sections". They are closely studied with reference to collision diagrams and accident-location histograms, and the sections with similar characteristics were taken out of the short list in order to avoid duplication of safety planning. Consequently, seven locations were selected.

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* The Study Roads extend to 316 Km. The criteria and the procedure for the selection of these roads are explained in Chapter 3.

Table 6.19 List of High-accident Location on the Study Roads During 1981 and 1982

Order by Total Number of Accident	Location		Number of Accident			Number of Fatalities	Number of Injuries	Remark
	Route No.	Kilo Post	Casualties	Property Damages	Total			
1	302	3	45	65	110	9	39	*
2	336	4	32	62	94	2	34	*
3	302	1	21	62	83	2	26	*
4	1	30	20	51	71	4	25	*
5	336	10	27	43	70	5	22	
6	1	21	35	34	69	6	34	*
7	302	0	26	43	69	2	26	*
8	336	2	39	30	69	2	40	*
9	1	31	29	38	67	7	46	*
10	336	6	23	43	66	1	24	*
11	302	2	38	27	65	14	49	*
12	336	7	27	37	64	4	27	
13	336	5	24	32	56	3	30	
14	336	8	16	38	54	3	14	
15	1	28	10	41	50	3	9	*
16	1	18	21	29	50	2	19	
17	1	29	7	29	46	2	7	*
18	1	19	22	22	44	5	17	*
19	336	3	22	20	42	3	22	*
20	336	0	18	24	42	2	18	
21	1	49	10	30	40	4	8	*
22	1	48	9	30	39	0	19	*
23	336	1	18	21	39	1	17	
24	1	50	11	27	38	8	21	*
25	306	1	16	19	35	2	15	*
26	1	20	20	14	34	3	18	*
27	1	34	12	19	31	12	33	
28	336	9	9	20	29	2	8	
29	2	254	24	3	27	11	31	*
30	1	17	14	13	27	3	16	

* The road segments included in safety planning sections

The route numbers, length of the selected sections along with the kilometer-post marking are as follows.

	Route No.	Kilo Post	Length (Km)
1)	Route 1	(KP 19+000-22+000)	3.0
2)	Route 1	(KP 29+500-32+500)	3.0
3)	Route 1	(KP 47+500-51+000)	3.5
4)	Route 302	(KP 1+000-4+000)	3.0
5)	Route 306	(KP 1+200-2+000)	0.8
6)	Route 336	(KP 2+000-5+000)	3.0
7)	Route 2	(KP 253+750-254+250)	0.5
		(Subtotal =	16.8)

Table 6.20, on the other hand, shows the top 15 of the records based on the total number of accidents involving pedestrians. The following two sections were selected because they had the highest numbers of fatalities.

	Route No.	Kilo Post	Length (Km)
1)	Route 306	(KP 13+000-14+000)	1.0
2)	Route 3113	(KP 1 +800-2+800)	1.0
			(2.0)

(2) Selection by Substandard-Alignment Criteria

The sections with poor alignments in road structure are selected through field survey. The following sites had problems in vertical and horizontal alignment, and some other structural deficiencies.

Problem in vertical alignment:

1)	Route 304	(KP 64+500-67+000)	2.5

Problem in horizontal alignment:

2)	Route 306	(KP 2+700-3+100)	0.4
3)	Route 205	(KP 1+300-1+700)	0.4
			(3.3)

Additional two sections were selected considering some obvious traffic flow problems.

Problem in high speed traffic:

1)	Route 32	(KP 52+500-69+500)	17.0

Problem of disorderly traffic flow mainly due to complex intersection:

2)	Route 2	(KP 254+500-255+000)	0.5
			(17.5)

(3) Concerns Expressed by the Relevant Parties

Finally, 3 more sections were selected based on interviews with the relevant parties, with whom the Team communicated through DOH counterparts. These sections were controversial and the demands for improvements were appealed from the local people and police.

1)	Route 323	(KP 79+500-80+000)	0.5
2)	Route 11	(KP 79+300-97+800)	0.5
3)	Route 1141	(KP 1+000-1+800)	0.8
			(1.8)

The safety planning sections summarized in Table 6.21 with reference to road classification by type in Figure 6.1, were reviewed and accepted by the DOH counterparts.

Table 6.20 List of High-accident Location on the Study Roads Involving Pedestrians During 1981 and 1982

Order by Total Number of Accident Involving Pedestrians	Location		Number of Accident Involving Pedestrians	Number of Fatalities	Number of Injuries	Remark
	Route No.	Kilo Post				
1	1	21	23	5	21	
2	336	4	19	0	20	
3	306	13	18	12	7	*
4	336	10	18	2	16	
5	336	2	17	2	16	
6	302	3	14	3	2	
7	3113	2	13	9	5	*
8	302	2	12	3	20	
9	336	3	11	3	10	
10	336	8	11	3	8	
11	1	20	11	2	10	
12	336	7	11	2	10	
13	1	19	10	3	7	
14	1	18	10	1	9	
15	336	0	10	0	10	

* The road segments included in safety planning section

Table 6.21 Safety Planning Sections

Road Classification by Type	Safety Planning Sections					
	Section No.	Route No.	Kilo Post of Beginning Point	Kilo Post of End Point	Problem in Traffic Safety	Length (km)
Roadway — Tangent Section — Normal	S 1	1	19+000	22+000	High frequency accident	3.0
	S 3	1	47+000	51+000	High frequency accident	3.5
	S 7	302	1+000	4+000	High frequency accident	3.0
	S10	306	13+000	14+000	High frequency accident involving pedestrians	1.0
	S11	336	2+000	5+000	High frequency accident	3.0
	S12	3113	1+800	2+800	High frequency accident involving pedestrians	1.0
Roadway — Tangent Section — Road Narrowing	S17	205	1+300	1+700	Problem in merging section	0.4
Roadway — Tangent Section — Crest, Sag	S 5	304	64+500	67+500	Vertical alignment	2.5
Roadway — Curve Section	S 9	306	2+700	3+100	Horizontal alignment	0.4
Intersection — Small Intersection	S 1	See "S1" in Roadway				
	S 4	32	52+500	69+500	High speed traffic	17.0
	S 5	See "S5" in Roadway				
Intersection — Medium Intersection	S 8	306	1+200	2+200	High frequency accident	0.8
	S11	See "S11" in Roadway				
	S13	11	97+300	97+800	Concerned by the relevant party	0.5
	S14	1141	1+000	1+800	Concerned by the relevant party	0.8
	S16	2	254+500	255+000	Conflict traffic	0.5
Intersection — Large Intersection	S 6	323	79+500	80+000	Concerned by the relevant party	0.5
	S15	2	253+750	254+250	High frequency accident	0.5
	S 2	1	29+500	32+500	High frequency accident	3.0
					Total	41.4

6.3.3 Supplementary Data Collection

Data for safety planning is required in three aspects: (i) geographical data; (ii) traffic data; and (iii) accident data.

Detailed maps were made by the Team by conducting the "topographic surveys". Types and sites of topographic surveys conducted for this study are shown in Table 6.22.

Table 6.22 Types and Sites of Topographic Surveys Conducted for Safety Planning

Description	Route No.	Total Length or Area
Plane-table Survey for Rural Area	323, 304, 32	8.4 Km
Plane-table Survey for Urban Area	302, 306, 336 3113, 11, 1141 2, 205	14.4 Km
Plane-table Survey for Intersection	1, 304, 301 302, 306, 336 343, 2	612,100 m^2
Cross-section Survey	304, 301, 302 306, 3113, 2	9.4 Km
Profile Survey	304, 3113	3.5 Km

Traffic data on volume by direction and type of vehicle crossing intersections were collected by traffic surveys conducted for this study.

Table 6.23 shows the locations where the traffic surveys were conducted.

Table 6.23 Traffic Survey Locations

Area	Route No.	Location
Rural Area	1	Kilo Post 32+500
	323	Kilo Post 79+900
Urban Area		
Near Bangkok	306	Kilo Post 1+500
	336	Soi 37
		Soi 53
Around Chiang Mai	11	Kilo Post 97+500
	1141	Kilo Post 1+500
		Kilo Post 1+550
Around Nakhon Ratchsima	2	Kilo Post 254+000
		Kilo Post 254+800